JULY/AUG 1983 Vol. 5 No. 4

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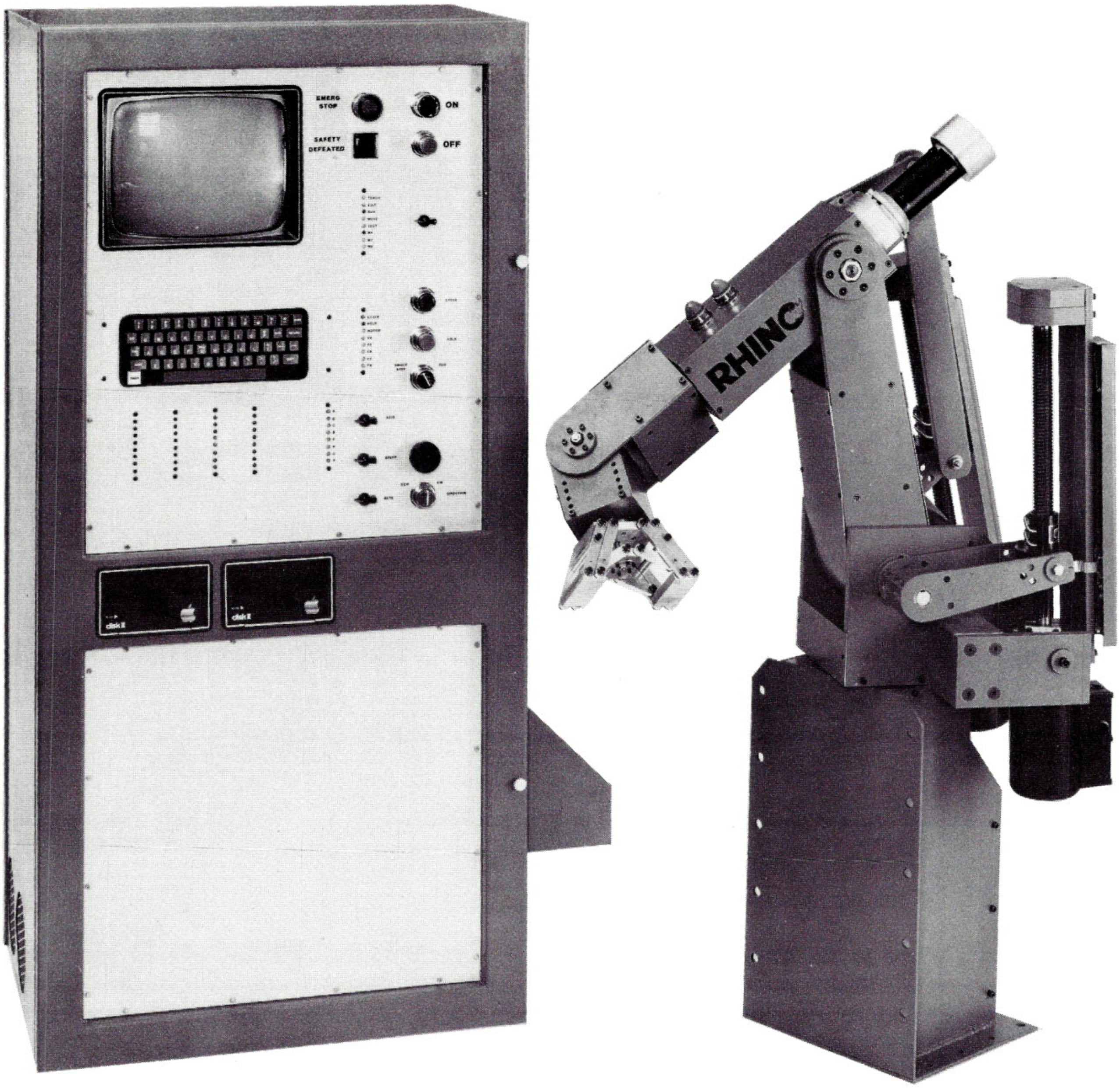

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CIRCLE 18

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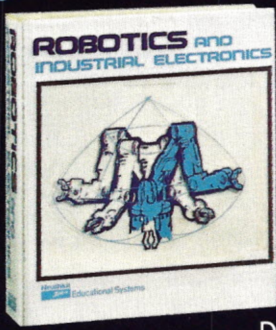

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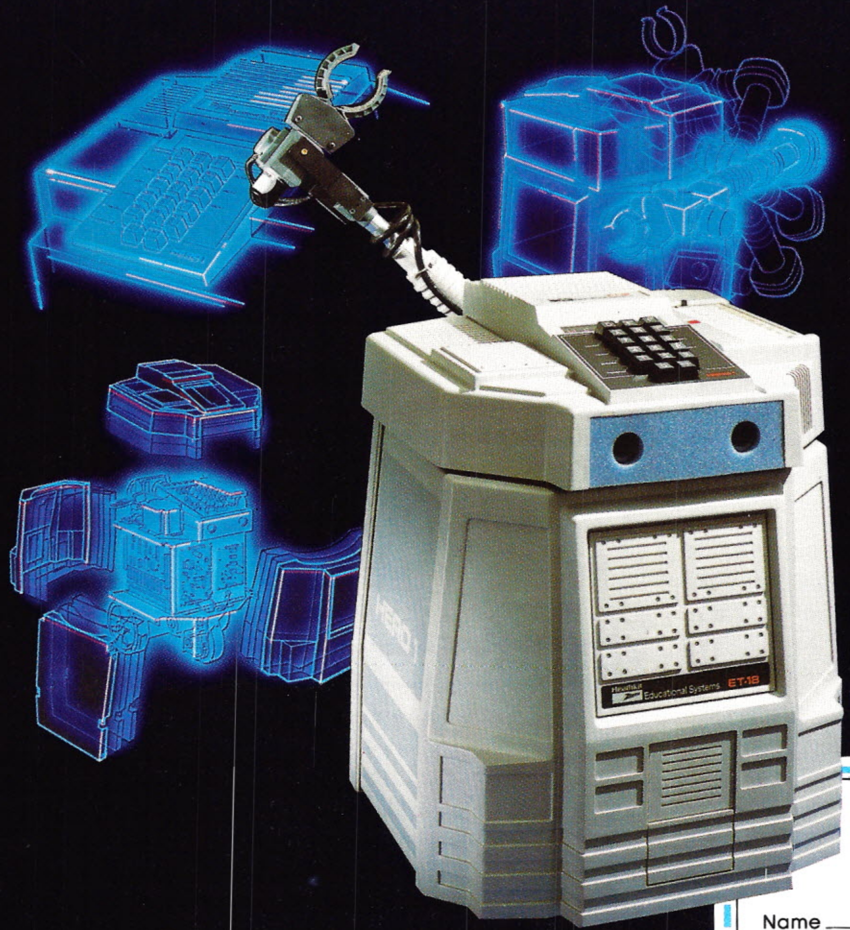

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CIRCLE 9

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THE JOURNAL OF INTELLIGENT MACHINES

ROBOTICS AGE™

JULY/AUG 1983 VOL. 5 NO. 3

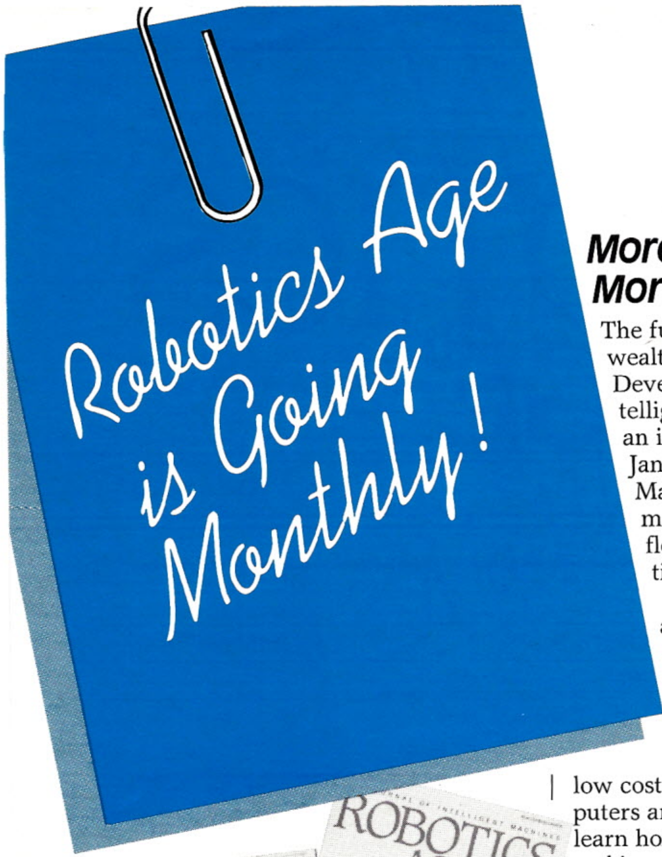
EDITORIAL

FEATURES

DEPARTMENTS

About the Cover: In this issue, we feature an article about one of the more exciting experimental applications of intelligent machine concepts: do-it-yourself space robots called "Get Away Specials." These self-contained modules can be designed, checked out, then flown on Space Shuttle missions for very reasonable costs. In order to work all the problems of the self-contained autonomous machine must be solved. Stan Kent, of Delta Vee, supplied us with the cover photo of a recent Shuttle launch (courtesy of NASA) to illustrate the theme of the article.

Incidentally, the Shuttle itself qualifies as a robotic system: oversimplified, it is a tightly coupled collection of real-time computers interacting with an environment of sensors and actuators under the overall command of its human pilots. All the reliability and performance design issues and potential problems of any real world robotic system are carried to extremes in the Shuttle's technology.



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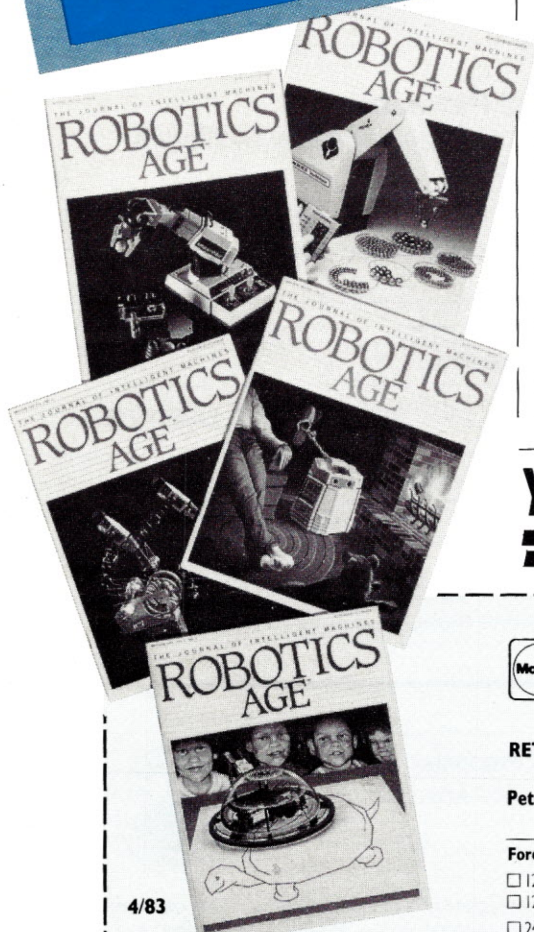

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Calendar

JULY

July 18–20, 1983. Understanding Robotics. University of Southern California, Los Angeles. Contact: Registration Services, USC, Los Angeles, CA 90089. (213) 743-2410.

This course provides a rapid introduction to the state of the art and current research problems of robotics. It develops a unified framework for understanding robotics and then examines individual technological components in detail. Each course section is designed and taught by an experienced educator with specialization in that particular subfield.

July 18–22, 1983. Computer Image Analysis. University of Michigan. Contact: Viola E. Miller, The University of Michigan, Continuing Engineering Education, Chrysler Center, North Campus, Ann Arbor, MI 48109. (313) 764-8490.

Robotic and biomedical applications increasingly require feedback control and quantitative information extraction from visually sensed environments. This course presents morphological shape analysis, parallel processing, and other computer vision technologies, with emphasis on solving practical problems.

July 25–29, 1983. Tenth Annual Conference on Computer Graphics and Interactive Techniques (SIGGRAPH '83). Contact: SIGGRAPH '83 Conference Office, 111 East Wacker Drive, Chicago, Illinois 60601. Phone: (312) 644-6610. SIGGRAPH '83 will offer more than 25 courses, 50 technical papers and panel presentations, an equipment exhibition, and classroom-style vendor presentations. Over 20,000 people are expected to attend.

July 25–29, 1983. Robot Manipulators, Computer Vision and Automated Assembly. Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Cambridge, MA 02139. Contact: Director of the Summer Session, Room E19-356, MIT, Cambridge, MA 02139.

This is a summer session course, designed to prepare the participant for the sophisticated methods soon to be employed in advanced automation. The emphasis will be on developing strategies for the solution of problems in sensing, spatial reasoning, and manipulation. The use of existing industrial robots and binary vision systems will be covered as well.

AUGUST

August 1–5, 1983. Robotics: Concepts, Theory, and Applications. University of Michigan. Contact: Viola E. Miller, The University of Michigan, Continuing Engineering Education, Chrysler Center, North Campus, Ann Arbor, MI 48109. (313) 764-8490.

Covers concepts and mathematics of computer-based robots. Topics include kinematics, dynamics and control, robotic lesion, integration of sensor information, robotic languages, economic justification, and applications. Laboratory sessions illustrate concepts presented in lectures.

August 8–12, 1983. Exhibition on the occasion of the Eighth International Joint Conference on Artificial In-

Continued on page 37

Editorial

The Wandering Roboteers...

Worldwide Impressions of an Evolving Technology

BY CARL HELMERS

Spring 1983 was an active and hectic travel time for me. As is usual for each spring for nearly a decade, I traveled twice to California. The first trip is always a round trip to the West Coast Computer Faire held in San Francisco, usually some time in March. The second trip is to join a shirt-sleeves gathering of designers, engineers, and researchers, sometime in April, under the auspices of a major engineering society. The complicating factor of this year's travels was an intermediate stop in Hannover, Germany. Now that this year's odyssey is over, I'll pass on some of the information I gathered in March and April.

Androbot and Topo-Logical Discoveries. I used the opportunity of my customary California trips to visit Androbot Inc. in Sunnyvale. I had first seen Androbot technology at a very hectic display in Las Vegas at the Consumer Electronics show last January. I wanted to visit Androbot's homeland to check on the progress of this new entry into the personal robotics field.

After the West Coast Computer Faire, my good friend Robert Tinney and I took a short side trip to Sunnyvale. Robert frequently does cover paintings for *Robotics Age* and other computer magazines. Our purpose was to visit Androbot and get to know what was happening. Our tour guide on this trip in April was Bill La, inventor of the incredible omnidirectional wheelchair (U.S. Patent #4,237,990). Bill works as an engineer for Androbot.

While at Androbot, we saw a bit of the future. The first major Androbot product to be readily available is the Topo version illustrated in these photographs and demonstrated in our recent visits to the factory. At the Winter Consumer Electronics Show in Las Vegas last January, Androbot had a big booth and demonstrated both Topo and a more elaborate version called B.O.B. (for Brain on Board). According to Nolan Bushnell, his goals with Androbot technology are to carry the technology of personal robots as far as possible.

The B.O.B. version, with its multiple processors and emulation of pet-like behaviors, will most likely be the first autonomous mass-produced robot. (As part of the Androbot engineering challenge, Nolan mentioned that Androbot is currently looking for a few mobile robot AI hackers with a good sense of practical implementation.) By the time you read this, we presume that the Androbot display at the Summer Con-

Editorial

sumer Electronics Show in Chicago will have happened—including further demonstrations of the B.O.B. version. As of early May, the Topo version, with its Apple-II interface and optional LOGO software, is the most widely available form. This series of photographs will serve as a starting point for a continuing stream of information about one of the novel designs entering the personal robotics marketplace.

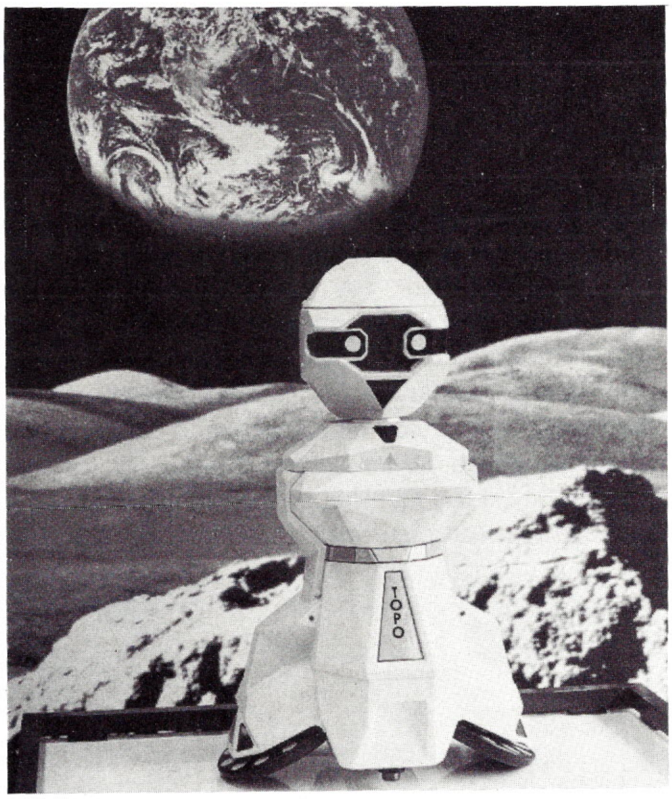


Photo 1. Androbot in full dress. Here we show a Topo version of the Androbot idea sitting in front of a wall mural on a lunar exploration theme.

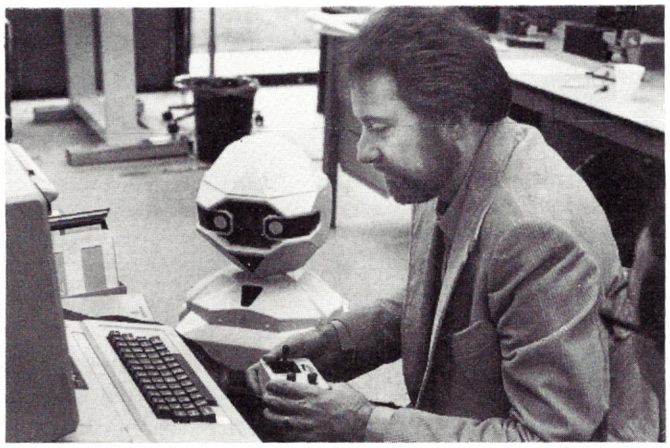


Photo 2. Artist Robert Tinney, at the joystick control, exercises Topo. The Topo form of the Androbot product is an output-only peripheral for Apple-II and Apple-IIe computers. Topo appears to be examining Robert's actions, a neat trick if Topo could do it. (Topo has no sensors.)

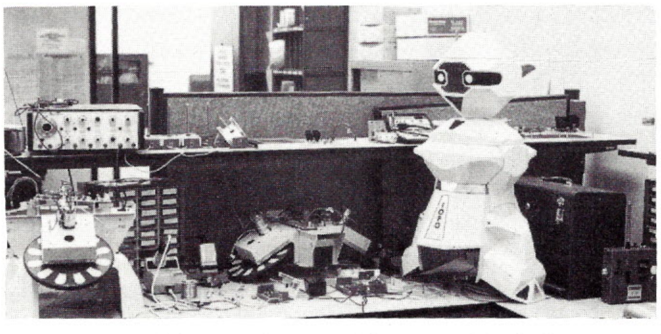


Photo 3. Every laboratory has a workbench, and Androbot's are no exceptions. Here we see a random picture of one bench setup among many that were present at Androbot. Real engineers do use soldering irons, too.

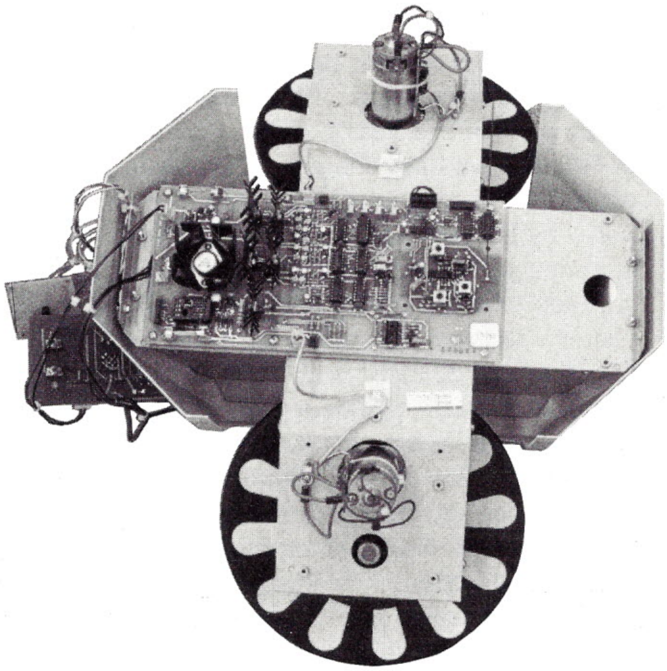


Photo 4. Removing a Topo's shell, we find the electronics of this simple personal robot. The electronics consists of a radio receiver, command decoding, and power drive electronics. Each wheel is individually commanded from the Apple computer, via the radio link. The joystick controls direction and relative speed of each wheel, giving its operator complete control of Topo's position. The receiver's antenna is a vertical whip extending upward within Topo's shell from a point near the right edge of the board in this photo. The batteries are mounted under the board, between the two wheels.

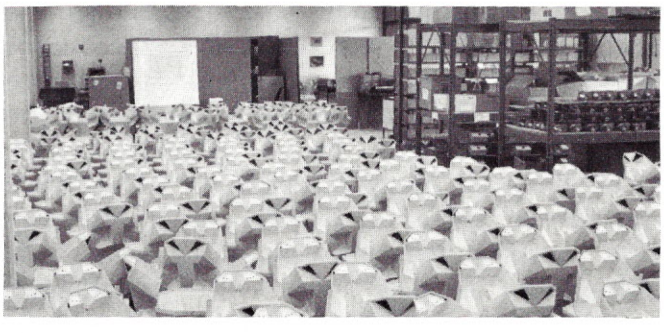


Photo 5. And more Topos (or B.O.B.s) are coming. As evidenced by this room full of shells, Androbot products are cranked out on a steady basis. One is tempted to compare this scene to images from the tale of the *Sorcerer's Apprentice.*

Editorial

Enough of Topo. Now let's travel 10 time zones to the east and take a look at robotics in the international industrial arena. This year, I had the good fortune to receive an invitation to attend the Hannover-Messe (Hannover Faire) in Germany. In cooperation with the Hannover Fair's organizers and Lufthansa Airlines (with ample promotion by the U.S. Department of Commerce, International Trade Commission) I joined a group of about 10 other representatives of U.S. professional organizations and trade publications.

The Hannover Fair (see photo 6) is sometimes called the "fair of fairs." Its scale is immense. In the seven days of this year's event, a preliminary count of 640,000 paid attendance was recorded. One fair official (who was immensely proud of this figure) noted by his estimate of an average visitor's 2½ day attendance, that the daily population of the fairgrounds was about 250,000 people. In this typical visitor's time on the grounds, he or she might attempt to see 23 halls with 500,000 square meters (about 122 acres) of indoor exhibition space. In between the walkways, this same visitor to the 250 acre fairgrounds can see an additional 200,000 square meters (about 50 acres) of outdoor exhibits.

We were asked to come and sample industrial and commercial activities in Europe. And sample is all that my colleagues and I could do. In a whirlwind three days at the fair, we were only able to get a flavor of the numerous pavilions on the fairgrounds.

The reason for the recursive nature of the nickname, fair of fairs, is obvious when you look at the nature of some of the exhibits. On the same grounds you find the international equivalents of many familiar North American exhibitions. For the intelligent machines and computer related parts of the Hannover Fair, it was like a simultaneous occurrence of some of the largest U.S. trade shows. The four halls of CeBIT were like NCC and a year's schedule of Comdex shows combined. At least three halls provide the simultaneous equivalents of the U.S. Electro and Wescon shows. The manufacturing halls with their heavy emphasis on robotic arms were reminiscent of the U.S. Robot shows (see Ray Cote's notes on Robot VII below.) There were halls and exhibits for many industrial specialties, from plumbing to construction equipment, from railroads to office interior design.

In one portion of CeBIT, Hall 3, there was a special U.S. Pavilion, arranged by the U.S. Commerce Department as a way of introducing U.S. companies to European export markets. This served as the central focal point for our wanderings around the fairgrounds. The main problem for a mono-lingual North American is the language barrier. I was able to utter and understand a few halting phrases of German recalled from my high school and college study of the language. What helped immensely for me, however, was the fact that modern high technology is like music, complete with universal themes and arrangements. There are only so many intended captions for signs about this or that robot arm or personal computer or bar code reader. Walking through a multi-lingual affair like this is a short course in equivalences of meaning.

Photo 6. A crowd scene from the fair of fairs. This picture was taken looking down about a half mile of walkway separating several permanent exhibition buildings on the grounds of the Hannover Fair. All 23 of the general exhibition buildings have identification numbers such as those seen in this photo.

The industrial robotics technology of the Hannover Fair was much like that seen worldwide. At the risk of oversimplification, there are only so many ways to conceive and fabricate a manipulator design. The universality of the technology was evident. Licensing is obvious. Thus we see in photo 7 an obvious combination of a Japanese company (Hitachi) with a German company (Zeppelin). Importation of North American technology into Europe was the goal of a Unimation booth (photo 8).

The robotics content of the Hannover Fair was hardly confined to that one hall. Scattered throughout the grounds and buildings wherever we went, we discovered intelligent systems and manipulators as part of displays. In CeBIT Hall 3, at the Zenith

booth, wonder of wonders, there was our friend Hero-I. Constrained in a narrow playpen amidst examples of various Zenith computers, Hero held forth. The virtues of erasable read-only memories were apparent, for this continental Hero spoke German instead of English (with the same Votrax accent, however). In another CeBIT hall we found concentrations of computer-aided drafting machines. A Japanese company called Mutoh Industries, Ltd. had a highly specialized output device for CAD use—a

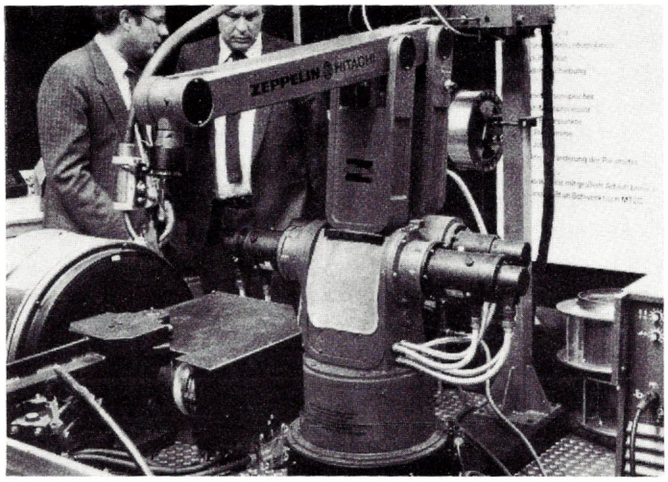


Photo 7. This Zeppelin-Hitachi manipulator, going through the motions of a welding operation, was typical of dozens of Hannover Fair exhibits in Hall 13, devoted to assembly, handling, and industrial robot equipment.

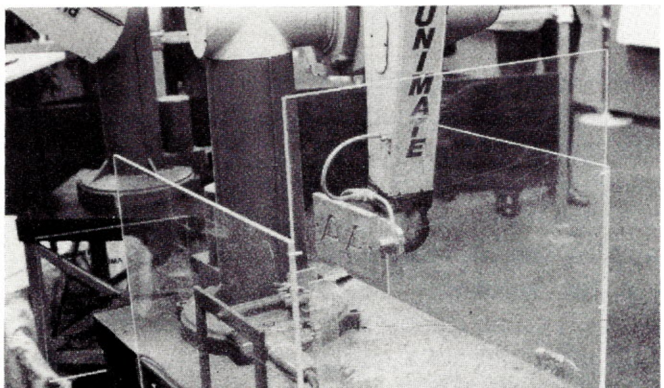


Photo 8. North American robot manufacturers were obviously present in Hall 13 at the Hannover Fair, as illustrated by this Unimate Puma. In this Unimate display, we see the arm grasping a wooden work piece, which is moved past a high-speed router bit to carve a set of initials in the wood. This was one of the few displays of an arm actually doing something. Many displays for operations like spray painting and welding had their arms executing appropriate motion programs, rather than actually painting or welding.

plotter adapted with knife blades to *cut* Rubilith film material used in the graphic arts industries. Other automated assembly equipment systems were seen in the various electronics halls.

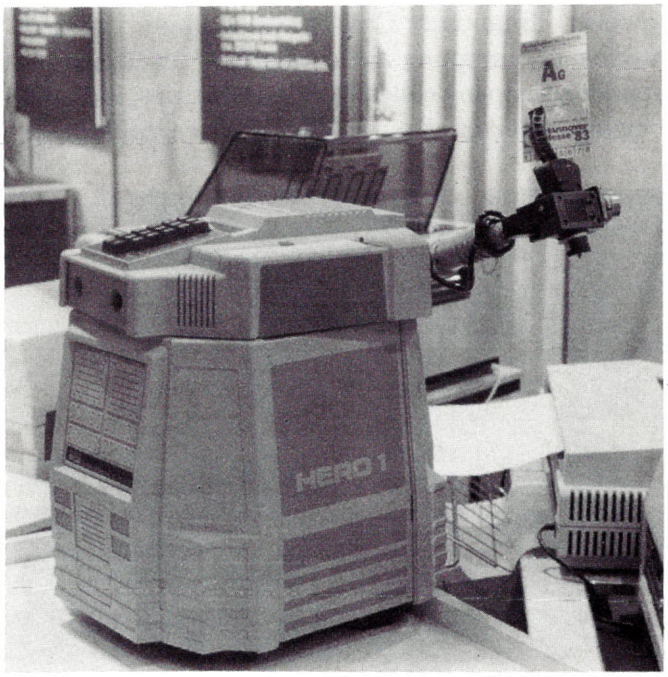


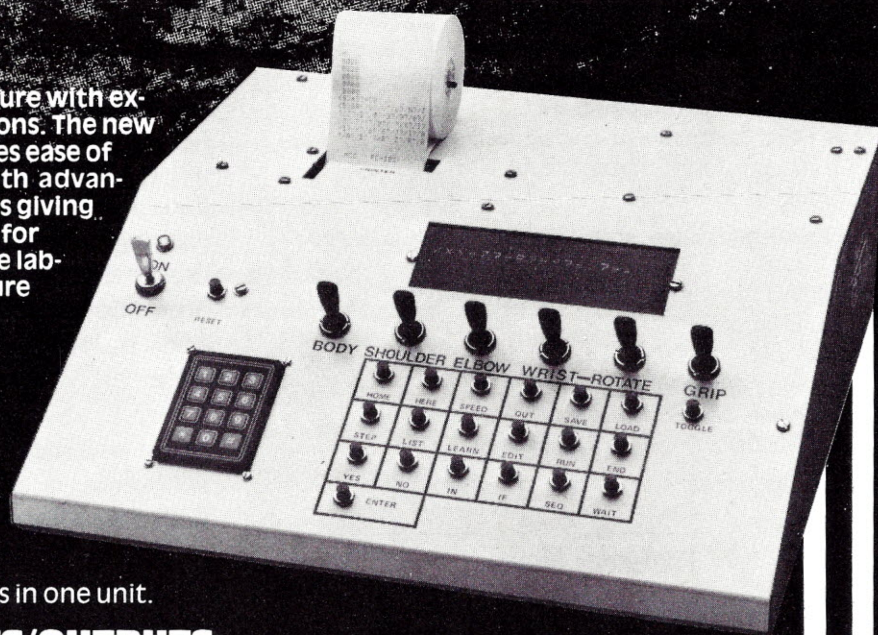
Photo 9. In this picture, posed with the help of the Zenith people at the booth, we see a Heath Hero-I holding a Hannover Fair entrance ticket. Hearing a Votrax voice output speak in German is an unusual experience.

If we extend the concept of robotics to the general field of intelligent machines, then much of the Fair concerned robotics. This extension is the basis of my definition of a robot as an interactive, real-time computer tool for human activities. Into this category we can place the personal computer, the automated factory, the automated spacecraft, and the general-purpose programmable manipulator. We can also include computer-aided design equipment, along with automatic office mail delivery robots. Such is the glory of this robotics age, that the technology of intelligent machines—silicon computer technology—can be applied in myriad ways.

I can only convey an impression of the Hannover Fair on paper. The event is many orders of magnitude larger than the few pictures and words presented here. Its message of the universality of modern technology is just as large.

BRIDGING THE COMMUNICATIONS GAP

...BETWEEN MAN and MACHINE



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Robotex is reaching into the future with exciting microelectronic innovations. The new RC-101 robot controller combines ease of programming and operation with advanced decision-making capabilities giving it virtually unlimited versatility for display use, the classroom or the laboratory. Join Robotex and venture into the world of Robotics . . . a glimpse of tomorrow!

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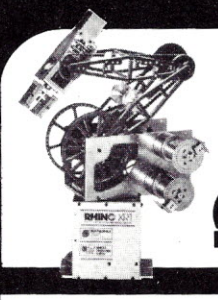
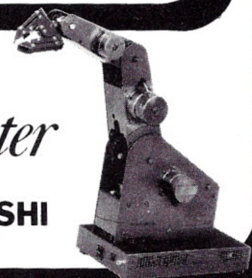
- **DURABILITY:** The RC-101 is constructed to withstand practical industrial use.
- **FLEXIBILITY TO CONTROL DIFFERENT ROBOTS:** The RC-101 is currently offered with software for driving Mitsubishi's RM-101 "Movemaster" micro-robot and Sandhu Machine Designs' XR-1 "Rhino." Software for other robots is forthcoming.
- **CASSETTE PROGRAM STORAGE:** This built-in feature allows control programs to be saved or loaded with a cassette storage interface.
- **SOFTWARE:** An **RTROL** language subset for the RM-101 or XR-1 is available for use on the Apple II + or Franklin Ace.



RHINO XR-1

SANDHU MACHINE DESIGN INC.



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CIRCLE 19

Hannover Fair Contacts

Here are two contacts relevant to the Hannover Fair, which may prove useful for readers planning trips to the 1984 version of the fair of fairs.

For general information about U.S. trade policies...
U.S. Department of Commerce
Judy Fogg, International Trade Specialist
14th Street & Constitution Avenue NW
Washington, DC 20230

For specific information about Hannover Fairs in the U.S....
Hannover Fairs Information Center
Delia Associates
PO Box 338
Salem Industrial Park
Whitehouse, NJ 08888
(201) 534-9044 (800) 526-5978

Publisher's Notes:
Rearranging the Masthead

Effective with this issue, we've changed several titles and rearranged the masthead to better reflect the actual functions of the people who bring you *Robotics Age.*

My long-time associate Ray Cote has a new title: editor. This better reflects his actual duties with respect to the preparation of *Robotics Age.* Ray began working for me as a co-op student from Northeastern University back in 1976, when I was editor of another pioneering computer publication. Since rejoining me in publishing activities in late 1981, he has been an essential element of the growth and progress of *Robotics Age.*

Also new on the masthead this month is Diane Mason, who joins our staff as editorial assistant. Perry Anable remains responsible for dealer sales and begins new responsibilities as advertising coordinator. Kent Richard has joined our full-time staff, with advertising sales responsibilities for the geographic territories not covered by our mid-Atlantic and northeast advertising representatives, CEL Associates. Donna Louzier joins our staff to assist Laura Hanson in her overall responsibilities for a new marketing department. Tobee Phipps joins our staff as an assistant in our business systems and circulation department.

As for myself, I continue doing the things that nobody else has time to do—constructing furniture, rebuilding computer hardware, writing miscellaneous essays for publication, creating occasional computer programs for use around the office, planning covers, planning our growth from a bimonthly to a monthly magazine next year, and acting as the decider of last resort.

Impressions of the Robot VII Show

BY RAY COTÉ

While Carl was at the Hannover Fair in Germany, a group of five people from the *Robotics Age* office left for Chicago and the Robot VII Conference and Exhibition held in McCormick Place. In a petite but exciting microcosm of manufacturing technology, this latest example of a series of U.S. Robot shows drew about 20,000 people. The notes that follow give a few random impressions of this display of robotics technology for manufacturing applications.

A company called Feedback had a turtle-like robot called an Armadillo. A related teaching robot, the Armadraulic, is a hydraulically operated, 5-axis arm with a two-finger gripper. It is programmed through a teaching pendant or an RS-232-C interface to a small computer. The Armadraulic product appears to be the only robot currently available for people wishing to experiment with inexpensive but complete hydraulically powered robots.

Of course, the Heath Hero-I was present and accounted for at the show. As usual, the Heath booth was swamped with crowds, so many visitors that Heath's literature supply ran out completely in the first day of the exhibition. (The Hero-I at Chicago did not speak to visitors in German, but it did have the same Votrax accent as the one described in Carl's account of the Hannover Fair.)

Microbot was present at Robot VII, displaying the older Teachmover series as well as a new industrial grade manipulator called the Alpha. The Microbot Alpha is rated to move 1.5 pounds (3.3 kg) at a velocity of 20 inches per second (51 cm/sec) within its envelope. The Alpha has optical position sensors on each axis, as well as an optional pneumatic hand manufactured by the Mack Corporation.

Rhino Robots also introduced a new industrial robot. This 4 foot (1.2 meter) tall robot had an impressive visage sitting in their booth. Yet we observed an Apple-II personal computer built into the controller rack—further evidence of the importance of small, inexpensive microcomputers in the industrial robotics field.

The prize for the most unusual arm-like manipulator at the Robot VII show has to be given to a company called Spine Robotics. The Spine is designed to

Editorial

paint the interiors of automobiles. Its application requires immense flexibility, achieved with a supple form that looks more like a tentacle than an arm (photo 10). The Spine manipulator consists of a number of small ovoids held together by two pairs of tensioned cables. These cables are connected to hydraulic cylinder actuators in the manipulator's base. Being well endowed with manipulative capabilities, the Spine's demonstration of prowess at the show was unique: it was programmed to pick up a basketball, wrap itself around the back side of a basketball backboard, then drop the ball through the hoop.

In designing the factory of the future, the subject of digital communications is one of the crucial problems to be addressed. As one solution to communication problems, Transensory Devices introduced their new Sensorbus at the show. This 4-wire bus uses RS-232 electrical levels and a communications protocol designed for sensors. The Sensorbus protocol allows random access to as many as 32 sensors connected to remote, communicating analog-to-digital conversion modules.

Transensory Devices also intends to provide silicon integrated sensors that attach directly to the Sensorbus. As integrated sensors created by micromachining techniques, the results should achieve higher reliability. (For more information on the subject of micromachining of silicon integrator sensors, see an excellent article by James Agell, Stephen Terry and Phillip Barth in the April 1983 issue of *Scientific American.)*

Continued on page 33

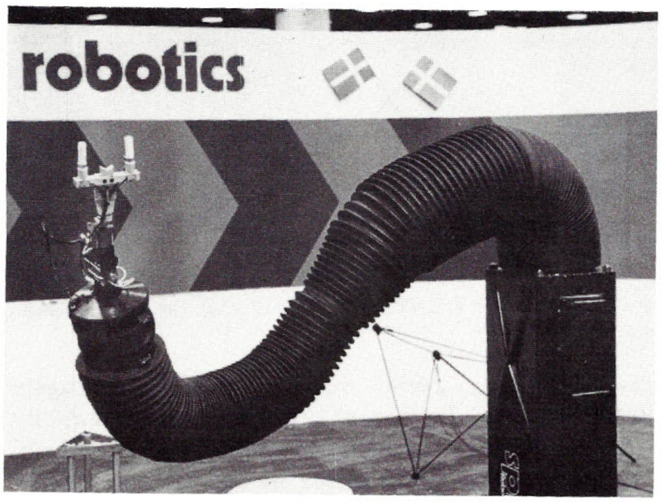


Photo 10. The Spine robot demonstrated its unusual flexibility.

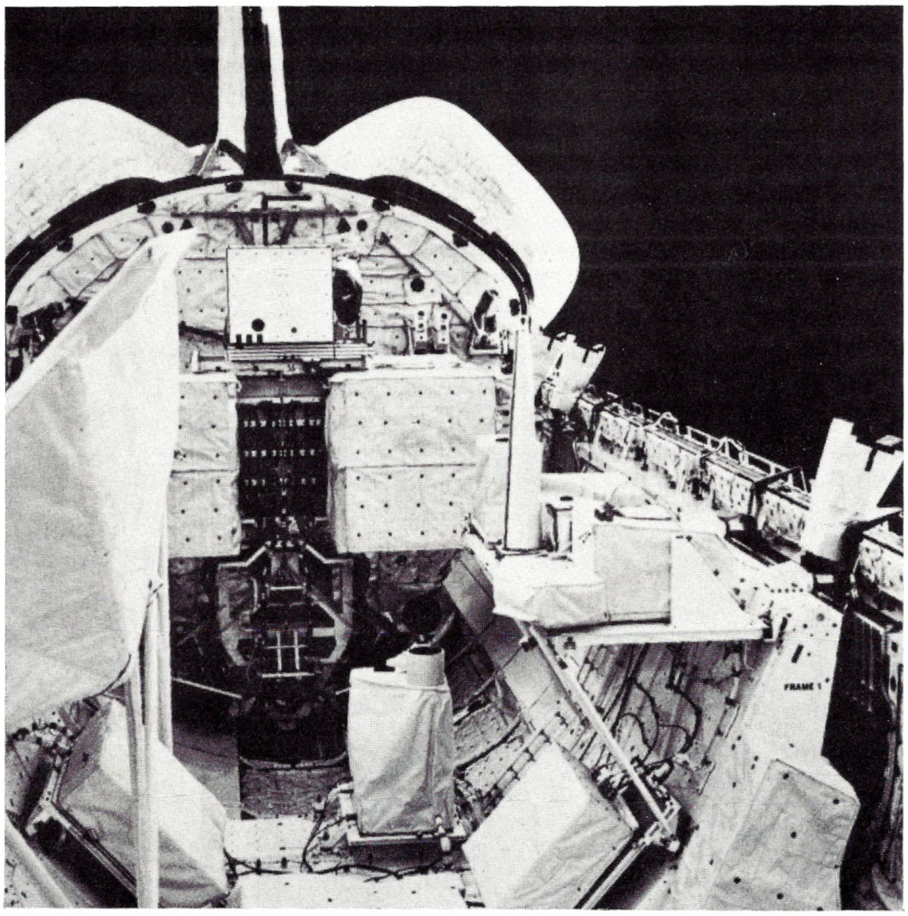
THE GET AWAY SPECIAL

PART I: SMALL, SELF-CONTAINED PAYLOADS

Steve Butow, Stan Kent,
Janet Major, Anthony Matthews
Delta Vee, Inc.
456 El Paseo de Saratoga
San Jose, California 95130

"We deliver!" proclaimed STS-5 Shuttle Commander Vance Brand, as the wheels of Columbia came to a successful stop on the runway of Edwards Air Force Base. These words announced the completion of the Space Shuttle's first commercial cargo mission. Delivering two commercial satellites into orbit, STS-5 carried the first private, commercial payload on an operational, manned, reusable spacecraft.

From now on, the Shuttle will carry one or more primary NASA, commercial, or defense-related payloads, and several small, self-contained (robotic) payloads (SSCPs). These small payloads may be purchased and built by hobbyists, scientists, universities, corporations, or foreign countries for their private use of the zero-gravity space environment. The self-contained experiments are offered by NASA on a space-available basis to encourage individuals and smaller companies to take advantage of the Space Shuttle in a low-cost way.



The bay is opened to space once the Shuttle achieves orbit. At this point, the astronauts can initiate the GAS experiments.

Although they are not the humanoid, android, or cyborg types of robots that are featured in Star Wars, Star Trek, and most outer-space media, the canisters that contain these experiments are making a name for robots within the space industry. The Get Away Special (GAS) canisters, however, were not the first, nor are they the only, robots to work in space. In some situations, a robot makes an ideal surrogate astronaut because of a robot's ability to function in a hostile environment. For instance, no astronaut has set foot on the barren landscape of Mars; yet we know a lot about Mars because of

Since this article was written, STS flight 6 has flown. Next issue, Part II will describe some of the experimental GAS results.

the work of a robot, the Viking Lander, which has sent us pictures and data about "the red planet." The robotic Voyager 2 spacecraft, which flew by Jupiter and Saturn, paved the way for future satellites, which will orbit these planets after being launched into space from the payload bay of the Shuttle.

Deploying a satellite or sending a large payload on the Shuttle usually costs millions of dollars. In 1982 dollars, the cost of a Shuttle flight is approximately $70 million to deliver approximately 50,000 pounds (20,000 kilograms) into low earth orbit. Such large sums of money do not encourage the testing of an entrepreneurial idea or the conducting of an educational experiment, so in 1976 NASA announced the Get Away Special Program as an affordable alternative for the average corporation or private group.

Each project is actually a payload inside a specific-sized canister. The canister is attached inside the Shuttle payload bay to conduct a specific mission using robotics technology. The canisters come in three sizes: 5 cubic feet (0.14 cubic meters) weighing a maximum of 200 pounds (91 kg) for $10,000; 2.5 cubic feet (0.07 cubic meters) at no more than 100 pounds (45 kg) for $5000; or 2.5 cubic feet and 60 pounds (27 kg) for $3000. To reserve a canister, an individual or group must make a nonrefundable deposit of $500. In comparison to the $100,000 deposit required to reserve a full Shuttle flight, GAS canisters are a bargain.

Photo 1. The Park Seed GAS experiment was designed to determine how seeds could be inexpensively shipped into space.

Student Involvement. The GAS concept was not proposed by the robotics industry. It was proposed by former NASA Associate Administrator for Space Transportation Systems, John Yardley. NASA latched onto the idea as a way of bringing youth into the space program. Involving young potential aerospace engineers, scientists, and technicians in the space program and training them to think logically about possible innovative space environment experiments became the GAS program's primary goal.

Gilbert Moore, an aerospace specialist with the Thiokol Corporation (the builders of the Space Shuttle's solid rocket boosters), brought the GAS program into the public's view in October 1976, with the first purchase of a Get Away Special the day the program was announced by NASA. Moore donated half of the 5-cubic foot (0.14 cubic meter) GAS to the students at Utah State University to do with it what they wished. Since then, Moore has purchased four more, to be donated to other educational institutions.

The reason behind Moore's generosity is twofold: first, to give future aerospace workers the opportunity to get a foothold in the industry while they are young; second, to stimulate the industry with new ideas. The first GAS payload, flown on STS-4, contained 9 experiments designed by 10 college students under engineering direction. The experiments were originally going to fly on STS-3—a flight during which the payload bay faced the sun for most of the mission. The mini payload was flown instead on STS-4, which had the payload bay oriented away from the sun. "Out of the 9 experiments flown, only two were successes," said Moore, "due primarily to thermal problems caused by the GAS canister being mostly in the shade."

The problem might have been avoided if a professional consultant

had been brought in early in the planning stages to do a thermal design analysis. This would have taken into account any changes in orientation and the insulation thus required. It was more difficult for the students to do this themselves, without the resources, speed, or expertise of a consulting firm. Consequently, a critical thermal blanket was omitted because the thermal analysis was not completed until after the lid was put on the payload at the Kennedy Space Center. The problems with GAS 1 on STS-4 were typical "learning" problems; yet they have not discouraged potential GAS users.

Not surprisingly, other interests picked up on the GAS concept for commercial purposes. Corporations are purchasing payload space for such uses as mixing metal alloys and pharmaceuticals with all the benefits of a zero-gravity environment. If these early GAS commercial ventures prove successful, more companies should begin reserving space.

Corporate Investment. One of the corporate GAS pioneers is the Park Seed Company of South Carolina. Park is flying a payload consisting of a wide variety of seeds to investigate the effects of exposure to the space environment (photo 1). The purpose of this experiment is to determine the best, fastest, and least expensive way to ship seeds into space, according to Dr. Jim Alston, one of the coordinators of the project. A long-term goal of this research is to find the best way to sell seeds for use in future space station greenhouses and gardens. "We're not interested so much in the reliability and uniformity of the growth pattern of seeds in space," said Alston. "We're looking more at the commercial aspects of sending seeds into space—whether seeds can be sent, and what is the most economical way to send them."

The Park Seed Company will send 44 kinds of seeds into orbit in different compartments and packages to test their exposure to different amounts of the space environment. There are also two identical control experiments left here on Earth. Since they did not use extremely complicated robotics systems, the Park Seed Company was able to develop and build its payload for under $2000. Using simple robotics techniques, the seeds will be rotated inside the canister so they receive uniform exposure to the space environment. Park also moved the completion date of the project from the end of 1984 to October of 1982, upon NASA's request.

The project was not without problems. "When we were halfway done, the structural engineers said the container would rupture. We had a week to rebuild, and we finished with three or four hours to spare." Alston said. "Since we're commercial, NASA could not help with the actual design and would not do a structural analysis. But as for working with us and helping us, they were tremendous."

Alston, who has a Ph.D. in plant breeding, said he would give the following advice to people who are starting to work on their own self-contained payloads:

- Start early, since experiments are flown on a space-available basis and you don't know what the waiting list will be.
- Use professional people, such as structural engineers, to help with your design.
- Work closely with the project manager assigned to your experiment.

While the experiment of the Park Seed Company is sitting at the launch site waiting for flight, Alston said that no matter what the results are, he will consider the project a success. "It's got to work—either we can send seeds up or we can't. I really think that we'll find that we haven't done any harm."

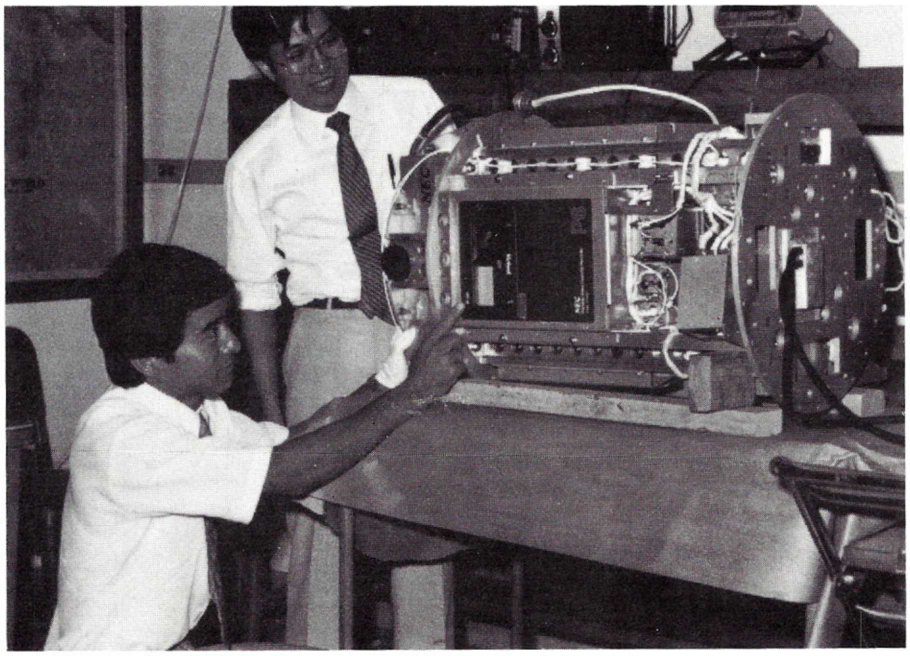


Photo 2. The Asahi Shimbun snowflake experiment explored the formation of snow crystals in space.

The Park Seed Company, however, is not the only company that thinks flying a GAS experiment will do them no harm. There is a lot of international interest in the GAS program from countries like Germany and Japan, which don't have national space transportation systems as flexible as the Shuttle. The GAS program gives people in other countries a chance to experiment with the space environment at a very low cost.

The Asahi Shimbun newspaper, based in Tokyo, has sponsored a payload to investigate crystal growth un-

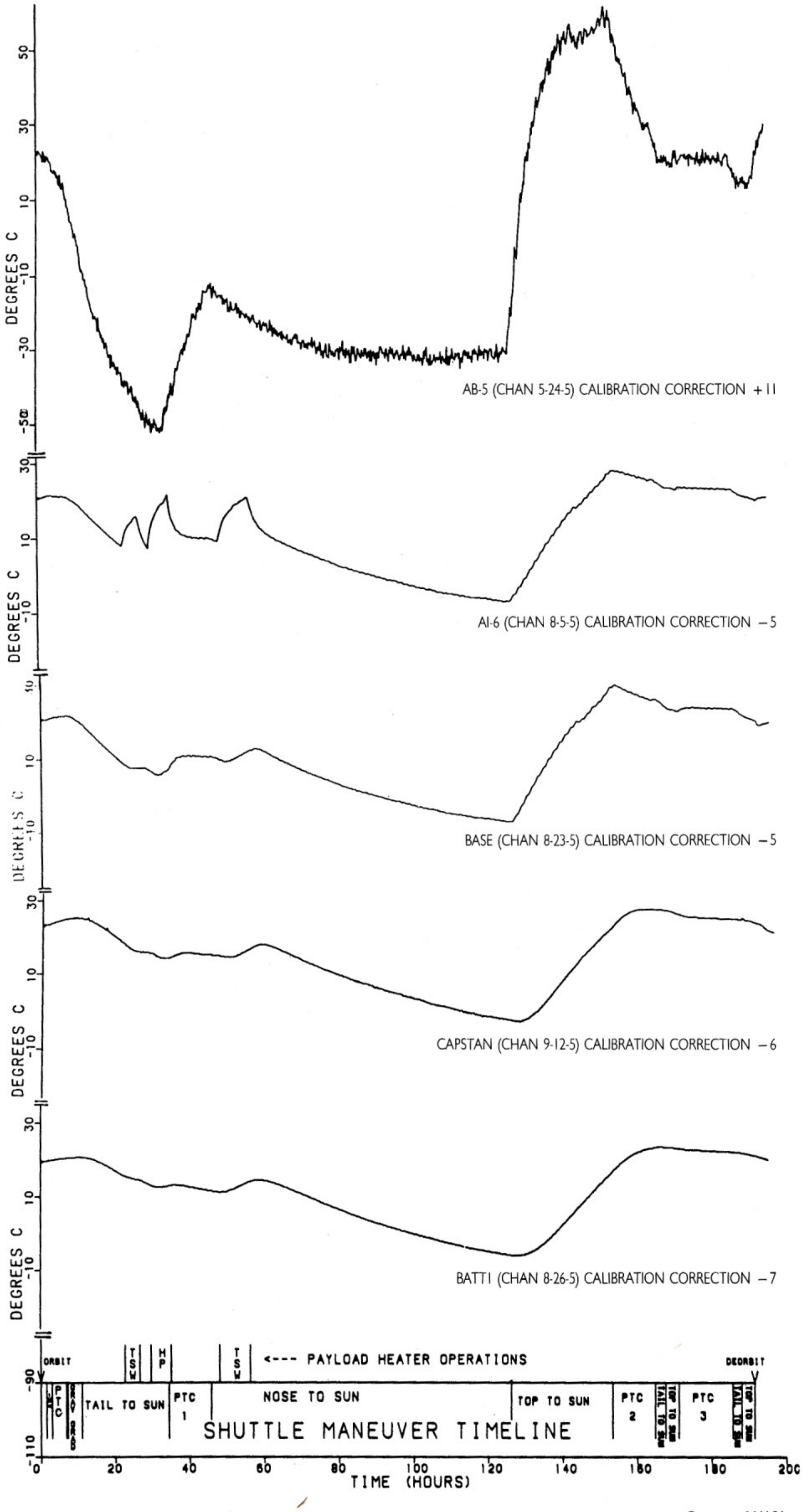
der zero-gravity conditions (in simpler terms, making snowflakes in space). This payload, shown in photo 2, incorporates two crystal chambers, two television cameras, four video cassette recorders, and a battery pack to power the whole payload. In keeping with the spirit of the program, the payload designers purchased most of the component parts of the payload off the shelf.

The Asahi Shimbun newspaper spent $330,000 to develop and build its complicated robotics project. The only human interaction with the experiment, according to officials of the Asahi Shimbun newspaper, will be turning on a main switch at 3 days and 15 minutes into the flight, and turning off the same switch at 3 days, 6 hours, and 50 minutes into the flight.

The idea for the payload was chosen from 17,000 ideas solicited from the readers of the paper. The objective, according to information from the Asahi Shimbun newspaper, is to observe the crystal growth of artificial snow in weightlessness. The snow crystals will be made in two small, cold chambers, and the process of the growth of the crystals will be recorded on video tape through optical systems and charge coupled device (CCD) cameras. The formation and growth of snow crystals will be repeated four times.

Officials at the newspaper said there are no commercial gains expected from their results. "Since this is a very basic experiment, we do not expect to find any direct commercial applications. But we hope Japanese scientists and engineers will soon follow us to do space experiments with commercial values." Even so, it is possible that Nippon Electric Company, which helped build the Asahi Shimbun payload, and other Japanese electronics corporations are looking at these crystallization results with a commercial eye. If space snow crystallization techniques can be applied to silicon crystallization, a lot of money can be made by building a better silicon chip.

Both these payloads were scheduled to fly on the sixth Shuttle flight.



Courtesy of NASA

Figure 1. Data taken from the GAS verification payload flown on STS-3. From top to bottom, the plots show the temperature histories for: the GAS adapter beam, the top and bottom of the GAS canister, the tape recorder capstan, and the battery.

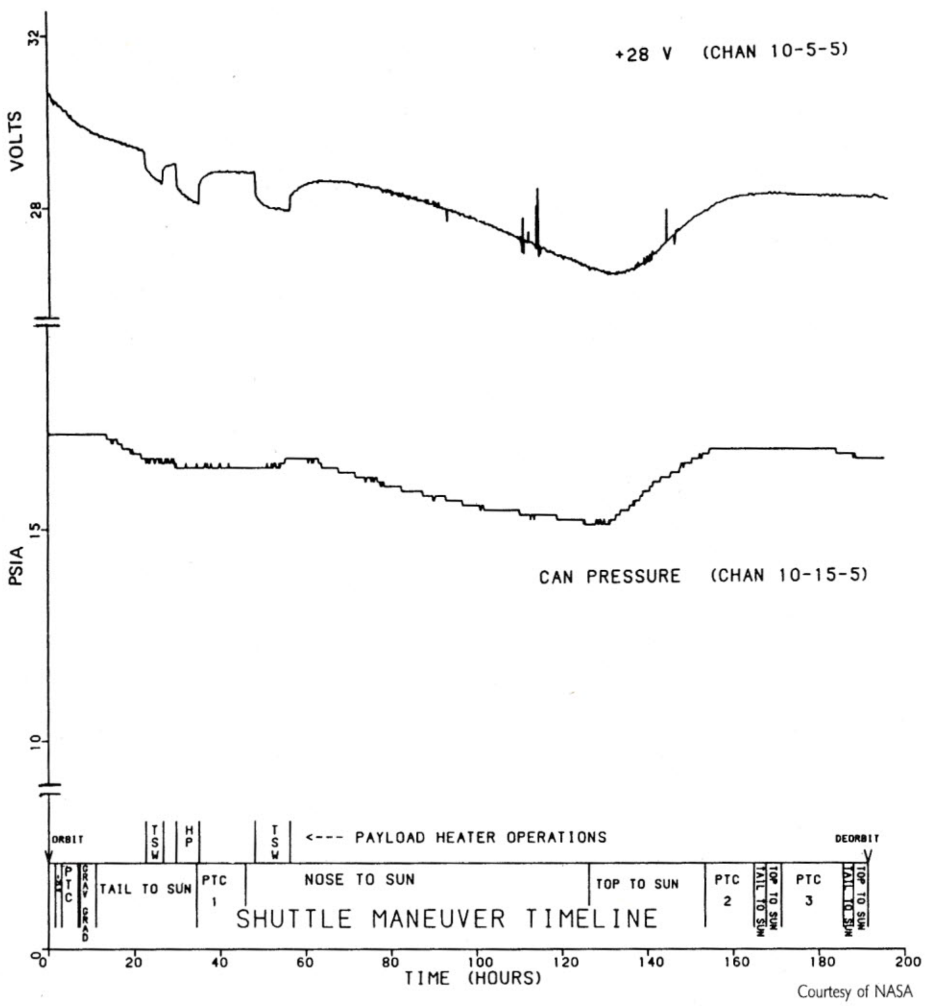


Figure 2. Data from the GAS verification payload, showing the battery voltage and canister pressure over the course of the flight.

Other payloads incorporate furnaces to study alloying of metals, and X-ray devices. An example of the potential diversity of payloads can be seen in the first GAS payload of Utah State University, which had a total of 10 different experiments. One was designed to study the effect of breeding fruit flies in space, and another to study the effect of alloying different metals in space. In order to determine that the GAS system would work with such a diverse range of experiments, NASA had to devise a way to test these small, self-contained experiments.

The GAS Verification Payload. To test the safety and reliability of GAS payloads, NASA built and flew an experimental model called the GAS Verification Payload (GVP) on STS-3. This successful flight, which was intended to provide GAS experimenters with flight environmental information, served also to develop the GAS support systems and work out programmatic problems.

The GVP mission tested and monitored the physical characteristics of the GAS container. A synopsis of the mission data available to the potential GAS user includes canister enclosure temperatures, canister internal temperatures, battery voltage, canister pressure, and analysis of the data film, illustrated in the preliminary data shown in figure 1. A Shuttle maneuver time line is superimposed to aid in interpreting the significance of the data.

Plot AB-5 is a history of the GAS adapter beam temperature. Although very different in shape, this mounting beam has mass and surface area within the same order of magnitude as the GAS canister. The temperatures shown, therefore, can be considered as roughly indicative of the surface temperatures that would be experienced by an uninsulated GAS canister. Plots AI-6 and BASE show the temperature history of the top and bottom of the GAS canister. Comparison of the data is testimony to the effectiveness of the passive thermal protection systems applied to the GAS canister.

Two areas of concern during design of GVP were the anticipated temperatures in the tape system and the battery. The CAPSTAN and BATT1 plots show that both subsystems experienced a nominal +15°C to −15°C over the mission. This temperature range is representative of all measured points within the canister.

Figure 2 shows the battery voltage and GAS canister history. Battery voltage dipped to 26.7V as the temperature bottomed out at −2°C. At this point, approximately 2kWh had been expended. This is half of the total 20°C capacity but is 75 percent of the 0°C battery capacity. The GAS canister pressure plot verifies that the canister properly maintained the slightly greater than 1 atmosphere pressure at which it was sealed prior to Orbiter installation. Preliminary examination of the film pack shows a background fogging very close to that of the reference film pack. This indicates that, for low inclination orbits, no additional shielding will be required for GAS experiment data film.

There were a few problems with the monitoring equipment. One pyroheliometer, one infrared sensor, and four temperature sensors (three external and one internal), failed to provide reliable data. In most cases, data was intermittent, indicating connection failure. Another potentially catastrophic problem was that one of the screws on the tape recording equipment came loose, but was miraculously captured by the tape early in the mission. It had been staked, prior to launch, but improperly installed. In this case no

data was ruined, and serendipity saved the experiment.

Building a Safe Payload. Let us assume that you've paid your money and you're ready to begin turning your idea into hardware reality. What is the first step? The answer is simple: consult the *GAS User's Handbook,* available from NASA, and become familiar with the GAS ground rules. Simply stated, the rules define an elementary robotics situation:

- To conduct the experiment, GAS users are allowed three switches attached to a hand-held controller, to be operated by the shuttle crew members.
- One of these switches must be dedicated to an on/off function, while the others have unlimited capacity to do whatever can be programmed into them. Examples of switch uses are thermal controlling, opening an experiment to space, and data collection.
- Performance of the experiment must not take up any of the crew's time, with the exception of throwing the three switches on and off.
- The experiment must not be a threat to the safety of the other payloads, and most importantly, to the crew.

The potential GAS user is confronted with a multitude of questions such as, "What are the restrictions on GAS payloads?" and "What does a GAS user have to do to get a payload approved for flight?" The payload must have a scientific or technological objective. Although NASA will not concern itself with the scientific merit of any experiment, the program does not allow, for example, the inclusion of a batch of space artifacts such as "This Flew On the Space Shuttle" buttons, simply for resale as a commercial enterprise. Other restrictions on payloads are largely design considerations.

To get a GAS approved for flight, the user has to show only that it is safe. The complete responsibility for design and construction belongs to each user, and the individual must do this without the help of NASA, although NASA will advise, if necessary. A typical GAS payload will include a structure, some batteries, associated electrical wiring connected to an experiment, and a microprocessor to control execution of the experiment.

Some of the things the GAS user would have to do to qualify this payload are: build a structure strong enough to withstand the highest loads that could occur, incorporate a large factor of safety, and produce an adequate structural analysis in support of this; test the batteries for operation and outgassing in a variety of situations and show the results of this test; show that the battery container is adequate to prevent any danger if a battery cell should fail; produce all electrical circuits and show that adequate protective devices such as fuses are incorporated; produce a complete list of materials and their uses and show that any hazardous materials, such as mercury, are properly contained; do some thermal analysis to assess how much heat the payload will generate and that this heat can be adequately dissipated through a proper thermal design, and that such temperature sensitive items as batteries will not react in any hazardous fashion to any possible temperature rise or reduction.

All this sounds far more ominous than it really is, and with a good design, a GAS user can easily meet all these requirements. When the safety assessment has been approved, the experiment will be ready for final assembly.

Next Issue. Part 2 will discuss the actual flight preparations for a GAS payload. We will also explore some future uses of robots in space. □

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57	67	77
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A NOSE FOR THE HEATH HERO-I

Patrick H. Stakem
Interface Technology Inc.
Box 745
College Park, Maryland 20740

This article discusses the implementation of a new sensor for the Heath ET-18 Hero-I robot. This unit, discussed in the March/April issue of *Robotics Age,* can sense light and sound levels as well as motion. The addition of auxiliary sensors was my prime goal. Several units were breadboarded before the robot kit was completed. I chose the kit version to become more familiar with the circuitry.

Although some progress has been made in vision, speech, and hearing systems, the artificial nose, except for certain highly specialized applications, has yet to be implemented. Mechanical "sniffers" exist for very specific aerosols and gases, and the home smoke detector uses an ionization chamber to detect products of combustion. I chose to adapt an existing smoke detector unit to the robot, since it was a working, well-defined subsystem with reasonable characteristics. The goal was to have the robot sense smoke and verbally raise an alarm. The robot would be aware of excess levels of particulate products of combustion in the air.

The smoke detector sensor is an ionization chamber with a small quantity of radioactive material. The

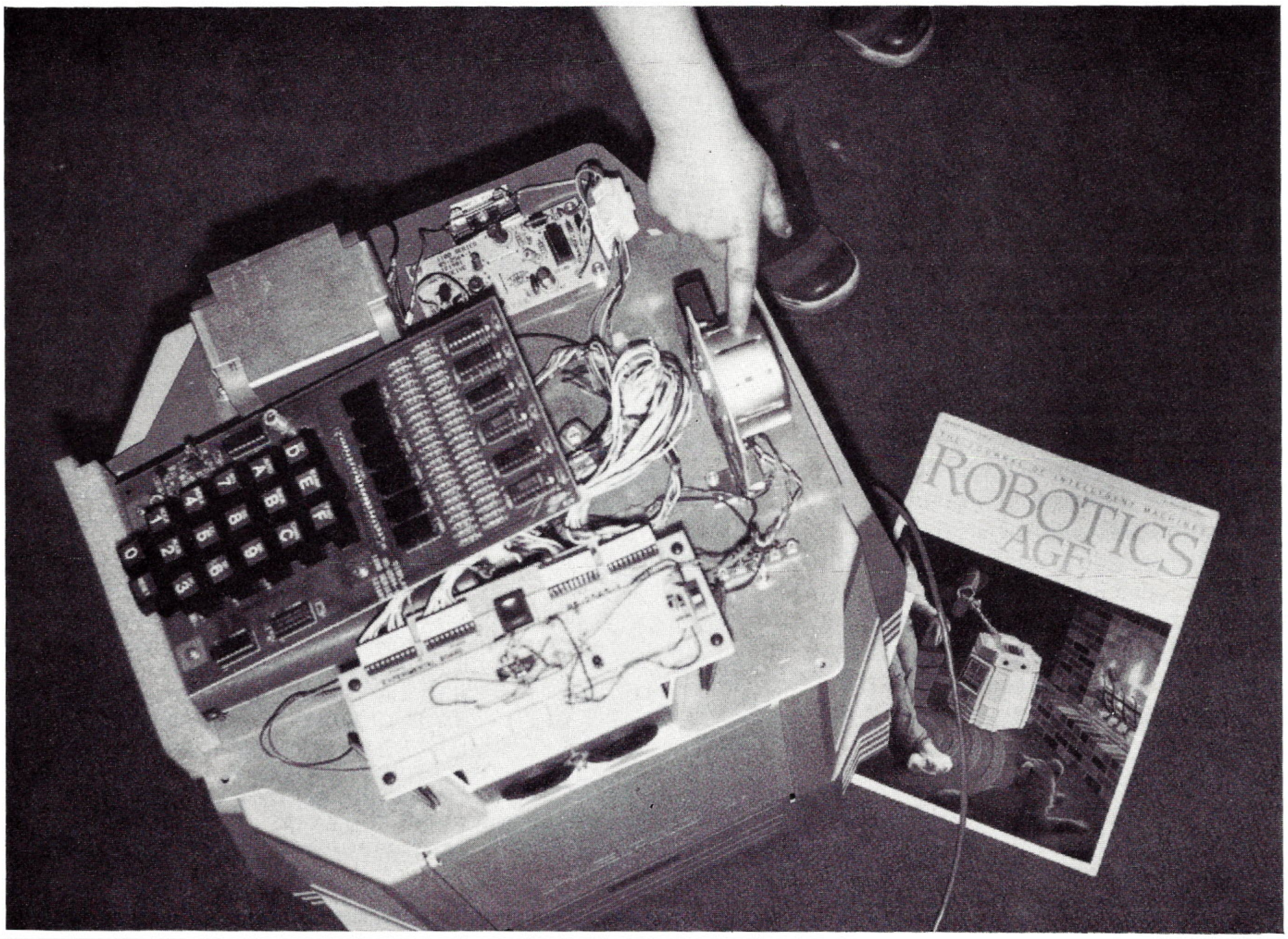

Photo 1. A top view of the Heath ET-18, showing the placement of the smoke detector.

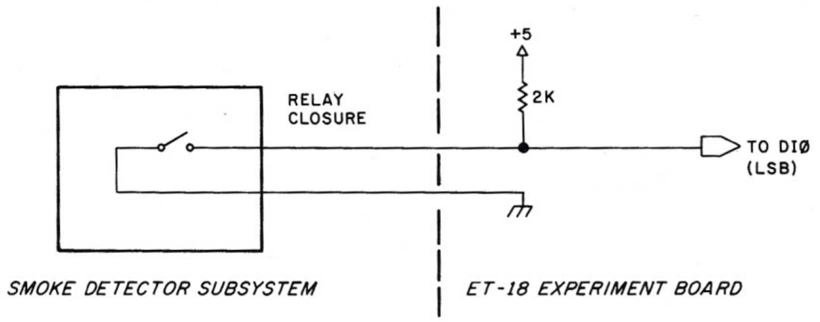

Figure 1. The smoke detector's buzzer is replaced with a simple relay. Triggering the smoke detector closes the relay and sets the least significant bit of DI to 1.

```
PROGRAM TO MONITOR SMOKE DETECTOR "NOSE" ON ET-18
ROBOT AS LSB OF C2A0 (EXPERIMENT BOARD)

ADDR      EQU      C2A0
MASK      EQU      01

NOSE      LDAA     ADDR
          ANDA     MASK
          BEQ      SMOKE

""""

SMOKE     (ROUTINE TO SAY "SMOKE") OR WHATEVER THE USER DESIRES
```

Listing 1. A simple assembly-language program is all that is necessary to monitor the new smoke detector sensor.

radioactive material ionizes the air, dust, and smoke particles that pass through the detector. An above average number of smoke particles sets up a current flow that is detected by a simple circuit and trips a loud alarm.

I chose a Sears 439-57301 unit, although the particular model is not important. I removed the circuit board from the plastic case and removed the buzzer unit from the circuit board. I replaced the buzzer with a 12V relay unit. The detector now trips the relay when enough smoke is detected. The circuit board is attached to the head of the robot, inside where the arm would mount. This detector will be moved when I add the robot arm. The detector should be mounted to allow a good airflow.

The relay output is used to change the state of the least significant bit (LSB) of the experiment board by the simple circuit shown in figure 1. Since the detector chip on the smoke detector board provides 9V (on my unit), with questionable drive capability, the relay isolation seems warranted. I retained the separate battery for the smoke detector, although the 9V could be derived from the robot's +12V supply.

Photo 1 shows the detector in place. The self-test feature was retained, making testing easy. A very simple program (listing 1) tests the LSB of the experiment board address (hexadecimal C2A0), to see if the detector is activated. If it is, the robot can take appropriate actions, such as announcing "fire" repeatedly.

The addition of a nose for combustion products seemed very much in line with the Hero-I's general-purpose nature and security role. If it's going to roam the house at night as a watchdog, it may as well do useful things.

This project also proved the simplicity of adding more sensors to the Hero-I robot, and the overall quality of the basic design. □

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58	68	78
Excellent	Good	Fair

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JAN/FEB 1982: Avatar: A Homebuilt Robot; A Look at SS-50 Computer Boards; Working Within Limits; Ambulatron: Another Contest Winner; Quester.

MAR/APR 1982: The Rhino XR-1: A Hands-On Introduction to Robotics; Power for Robots; A Computer Controlled Sentry Robot: A Homebuilt Project Report; Natural Language Understanding: A First Look; RT-13 Video/Sound Recognition System; An Inexpensive Hand; Type 'N Talk.

MAY/JUNE 1982: Part Sources for Robots; An Inexpensive Arm-Hand System; The Polaroid P100 Polapulse Battery: Solution Waiting for a Problem; New Robot Books for the Bookcase: Applying Robot Vision to the Real World; Robots VI: A Landmark in an Exciting Era; Photo Essay and Notes from Robot VI.

JULY/AUG 1982: The Microbot Teachmover; Some Notes On the Rhino XR-1 and Minimover 5; Patent Probe; Use Your Apple As a Robotics Development System; IBM Robots; Adapting A Speech Synthesizer; Constructing An Intelligent Mobile Platform, Part I.

SEPT/OCT 1982: Roving Robots; Report on SIGGRAPH '82; Patent Probe No. 4,221,997; Constructing an Intelligent Mobile Platform, Part II; The Physics of One-Legged Mobile Robots.

NOV/DEC 1982: Robot Wrist Actuators; Patent Probe; A Microcomputer Based, Real-Time Robotics System; The Physics of One-Legged Mobile Robots, Part II; 1982 AAAI Conference; Armatron: A Study in Arm Engineering; Invention Documentation: A Primer.

JAN/FEB 1983: The Move-Master RM-101; Mailmobiles in the Office; Teaching the Rhino XR-1 to Write; The Philosophy and Birth of Computer Science; The 2-Roll Gripper.

MAR/APR 1983: Nuclear Power Plant Emergency Damage Control Robot; Artificial Intelligence and the Nature of Robotics; Patent Probe: Driverless Vehicle Autoguide; Lamberton Robots.

MAY/JUNE 1983: Patent Probe: Multi-Purpose Mechanical Hand; XY Interpolation Algorithms; Designing With Optical Shaft Encoders; A Table of Contemporary Manipulator Devices; An Algorithmic Approach to Intelligent Robot Mobility.

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AMBULATORY PLATFORM

Russ Adams
3008 Mosby Street
Alexandria, Virginia 22305

The recent introduction of several home ambulatory robots has rekindled interest in robot locomotion. These movement mechanisms have been somewhat neglected in the research arena in preference to the hot areas like robotic sensors and manipulator controls.

One interesting drive mechanism is not in a robot at all, at least not a robot in the traditional sense. The drive is found in a device that is closely related to robotics—a motorized paraplegic ambulator, or wheelchair.

Patent number 4,258,815, issued to John P. Wier and Robert A. Garrett on March 31, 1981, describes an ambulator drive mechanism of minimum size, with a low center of gravity and maximum maneuverability (see figure 1).

The invention describes a drive mechanism for a mobile platform that supports a paraplegic in a standing position. The platform functions also as the chassis for the drive. The platform is constructed to be as small as possible to permit access to even confined areas. This feature is of importance to robot drive mechanisms as well.

The mechanism's unique design enables easy movement along any of the three axes of motion. Easy maneuverability is also important in robotics.

The illustrations in Patent Probe are reproductions of diagrams in the original patent documents.

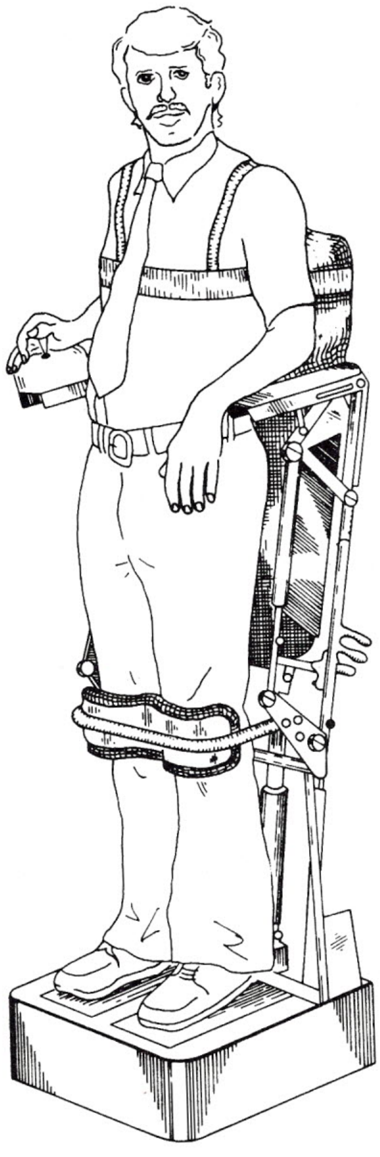

Figure 1. A perspective view of the ambulator in action.

The drive is constructed with a set of four wheels. Each wheel is mounted at a corner of the platform (figures 2 and 3) and is pivoted to rotate around a generally vertical axis. Rollers are mounted around the periphery of each wheel. The axis of each roller lies in a plane perpendicular to the vertical axis of each wheel.

The wheel assembly is mounted to the chassis at an 18 degree tilt with respect to the ground. As a result of the 18 degree inclination, only one or two of the outermost rollers contact the ground at any one time. This tilted mounting is the secret of the ambulator's ability to maneuver easily.

The preferred design for the ambulator consists of a platform formed as an 18″ × 18″ × 5″ rectangular box (figure 4). A chassis (18) is bolted within the platform. The wheel assemblies (A, B, C, and D) are mounted at each of the chassis' four corners. Connected to each wheel assembly is a DC reversible motor, which drives the wheel about its inclined axis of rotation.

The preferred motors are flat printed circuit motors like those sold by the PMI Division of Kollmorgen Corporation of Glen Cove, New York. The electronic motor control circuits are housed in four compartments under the chassis.

A battery power supply for the

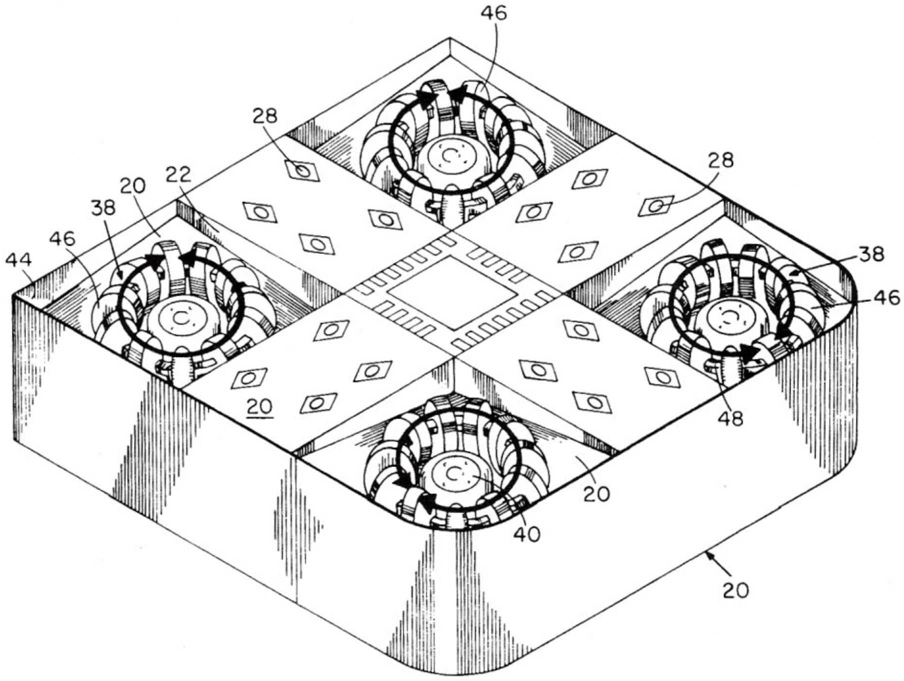

Figure 2. The details of the four drive wheel assemblies as seen from the bottom of the platform.

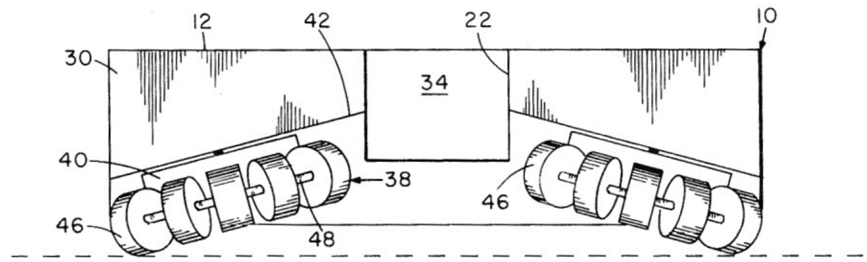

Figure 3. Cross-section view of the platform, showing the inclination of the wheels.

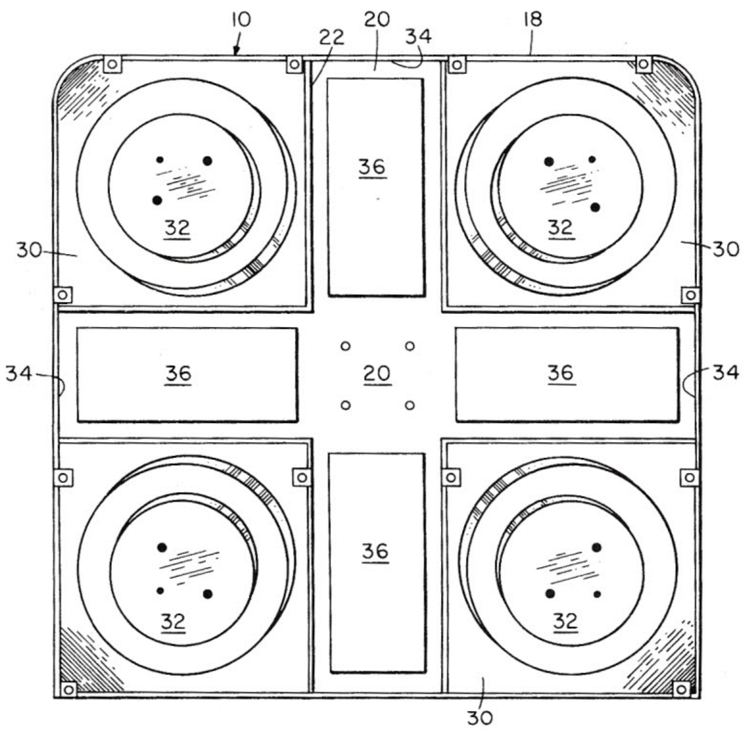

Figure 4. Top view of the platform with its top plate removed. Shown are the motors (32) and batteries (36).

drive motors is mounted under the platform center. The battery supply is a rechargeable 2 volt, 30 amp/hr. gel-cell such as the "Carefree Rechargeable Battery" marketed by the Eagle Picher Co.

Each of the wheel assemblies can be made of plastic. Each consists of a hub (40) and a plate (42). The rollers are equally spaced around the circumference of the wheel and are mounted to the plate by loosely fitting pivot shafts (48). Each roller freely rotates on these shafts. Teflon® may be used to fabricate the rollers.

The hub of each wheel is rotatably mounted on a bearing shaft (52). The inner race of the bearing is welded to the drive shaft of the motor (32). This construction permits the motor to rotate the plate and rollers about the inclined axis.

As mentioned, the inclination is critical to the unique operation of the invention. The canted angle of the wheel assembly limits the number of rollers that touch the surface over which the device is to be propelled.

The direction of platform movement depends on the combination clockwise and counterclockwise rotation of the four wheel assemblies. Table 1 lists nine wheel assembly rotation combinations and the resulting platform direction. A minus sign indicates a counterclockwise rotation, while a plus sign indicates a clockwise rotation, as viewed from above the platform.

The patent discusses a related patent. Patent 4,054,319, issued October 18, 1977, discloses an invention titled "Stand-Aid Invalid Wheelchair." This related patent discloses a wheelchair with a linkage to move a paraplegic from a seated to a standing position. Inventors Weir and Garrett indicate that this patent lacks the maneuverability of their mechanism.

Also mentioned are several pending US patent applications. Patent applications are generally not available to the public unless they are mentioned in an issued patent. These related applications are serial num-

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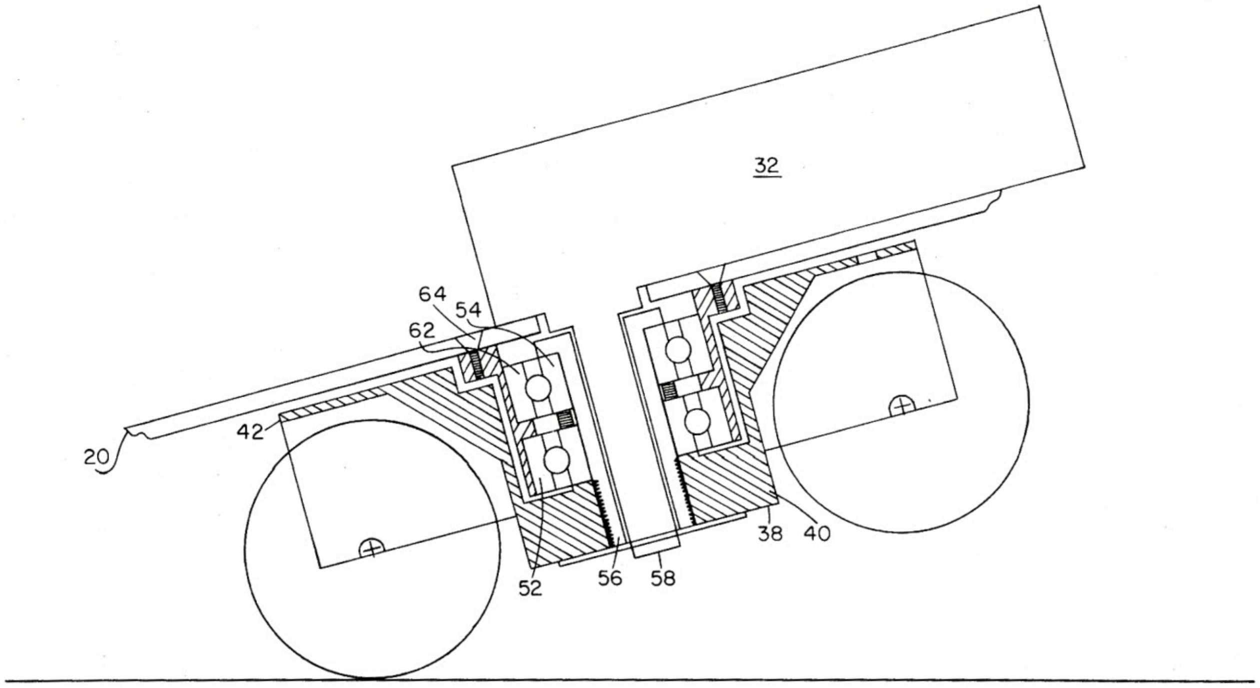

Figure 5. A cross-section view of a wheel assembly.

Table I

Platform Direction	Wheel Assembly Rotation
Reverse	+A, −B, +C, −D
Right	−A, −B, +C, +D
Left	+A, +B, −C, −D
Slew 45°	−A, +D
Slew 135°	−B, +C
Slew 225°	+A, −D
Slew 315°	+B, −C
Clockwise rotation	−A, −B, −C, −D
Counterclockwise rotation	+A, +B, +C, +D

Table 1. A + indicates clockwise rotation; a − indicates counterclockwise rotation as viewed from above the platform.

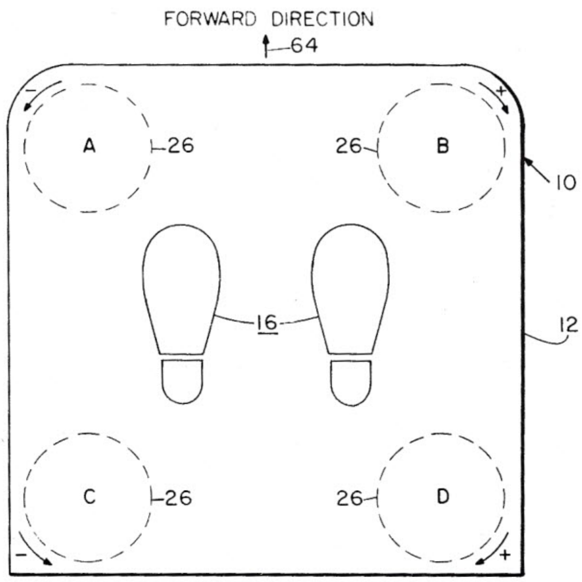

Figure 6. A schematic top view of the platform, showing one combination of wheel rotations, along with the resultant direction of the platform.

ber 05/955427, filed October 27, 1978 (now patent number 4,284,929), titled "Ambulator Control Circuit," and serial number 06/062835, filed August 1, 1979, titled "Integrated Wheelchair and Ambulator."

Copies of Patent 4,258,815 and the other patents mentioned are available from the US Patent and Trademark Office for $1.00 each. The patent applications mentioned here are available for inspection at the US Patent and Trademark Office, Public Search Room, Arlington, Virginia. Orders for patents should be sent with payment to: Commissioner of Patents and Trademarks, Washington, DC 20231. □

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Sensory Perceptions

BY TED BLANK

"IS MY CHESS OPPONENT A HUMAN OR A MACHINE?" In August 1983, the Chess Prize Competition of the National Conference on Artificial Intelligence will use both computer programs and chess masters as competitors, so that the opponents won't know until it's over who their adversaries were. ***Computers and People,*** March/April 1983.

A ROBOTIC NOSE? The University of Warwick, England, is building an electronic sniffer, or bionic nose, with 400 odor receptors connected to a microchip to distinguish smells. About the size of a pocket calculator, it will first be used in the cosmetic industry. ***Wall Street Journal.***

STICKY STUFF. Robotic applications of adhesives, sealants, and caulking materials are features of a system from Nordson Corp. of Amherst, Ohio. It uses an electric manipulator holding a hot melt gun with 2000 possible positions. This system is licensed from Yasakawa Corp., Japan. ***Automation News,*** March 1983.

A ROBOT'S WORK IS NEVER DONE. "A robot that does *all* the work in the home is at least 20 years off," according to Kevin Dowling, a researcher at Carnegie-Mellon University. The difficulty of a somewhat inflexible device operating in an unstructured home environment is only the first problem, he notes. The biggest problems will be to find enough work to keep it busy for more than two hours a day and the legal implications for liability in case of accidents with people or property. ***OMNI,*** April 1983, p. 50.

OLD TOOLS. More than 34% of US machine tools are over 20 years old. In Japan, only 18% are this old, with 61% fewer than 10 years old. Since the machine tool business is central to the growth of all manufacturing, it is a matter of some concern that Japan already has more than 50% of the US machine tool market. It is also surprising that only 4% of US machine tools are numerically or computer controlled. ***Fortune,*** February 21, 1983, p. 58.

X-Y-Z ROBOTS IN THIS CORNER. Electronic assemblers now claim that robotic arms with straight-line movements, the three-axis, X-Y-Z type, are most suitable for high-precision lightweight work. New models offer 0.001 inch accuracy and repeatability. Polar or revolute arms are better in confined spaces. ***American Machinist*** March 1983, p. 116.

LOWER PRICES FOR MACHINE VISION. Simplifying the software using a 6-bit flash analog-to-digital converter enables Intelledex, Corvallis, Oregon, to offer a machine vision system for under $16,000. Most competing systems average $35,000. The Intelledex system is addressed with BASIC and 30 dedicated vision commands, minimizing microcode requirements. It also can be integrated with the Intelledex model 605 robotic arm, which is currently used for testing printed circuit boards. ***Electronic Design,*** March 3, 1983.

IF IT LOOKS LIKE A SNAKE AND CRAWLS LIKE A SNAKE, IS IT A SNAKE? Toshiba Corp., Kawasaki, Japan, has developed an inspection robot that is 7 feet long with eight universal joints in the form of a snake to inspect inside pipes and small areas of nuclear power plants. The device contains a video camera, 56 touch sensors, 34 limit switches, 17 position sensors, and 16 motors. ***Automation News,*** March 1983.

ONE-STOP SHOPPING FOR THE HANDICAPPED. As more computer-based and robotic devices for the handicapped appear on the market, it was only logical to assume that a company would assemble them into a single catalog. The Handicapped's Source, 526 Langfield, Northville, Michigan 48167, lists in its catalog: 6 environmental control systems, 15 communication systems (including 2 voice recognition types), 6 special switches, over 70 software packages, and all of the popular microcomputer brands that run the software. The only directory which may be larger but probably not as current is the *Directory of Living Aids,* produced by the Veterans Administration and available for $7.50 from the Superintendent of Documents, USGPO, Washington, D.C. 20402 (stock # 051-000-00158-3). ***The Handicapped's Source Catalog.***

FASHIONABLE ROBOTS. The Japanese apparel industry, facing competition from southeast Asia, has begun a seven year project to develop robots that will design, cut, sew, finish, and inspect clothing. The Ministry of International Trade and Industry will spend $65 million for robots with sight and touch integrated with computer-controlled design and cutting systems.

Other nonmanufacturing robotic applications in Japan scheduled to start in 1985 include insecticide spraying, egg inspection, fertilizer spreading, and cargo handling. By 1990, this robotic category is expected to be a $360 million business that will include robot nurses, guides for the blind, and street sweepers. ***Industrial Automation Reporter,*** March 1983.

NEWS POINTS. In the world market for industrial robot arms, Unimation has 15% market share with Cincinnati Milacron at 3%. In the US, these two have 50% market share combined. Right behind Unimation on the world market, in a three-way tie at 13% each, are Kawasaki, Fujitsu Fanuc, and Hitachi. It is interesting to note that Kawasaki is the Unimation licensee, indicating that, perhaps, Unimation created its own competition.

Many US mills have a mish-mash of 100-year-old machinery fitted with

Sensory Perceptions

two-year-old controls and add-ons. This piecemeal investment fails to yield the productivity and quality improvements that the new equipment was supposed to bring.

Downriver Community Conference, a consortium of 16 towns in Michigan for retraining unemployed workers, has had 2400 people go through their courses. More than half have gone back to work but at a pay cut of 10%. The program also seemed to have little value for workers aged 54 and over; the reasons for this were not cited. ***Wall Street Journal,*** March 30, 1983, p. 29.

WELDING GAP. Arc welding equipment manufacturers in the US are joining forces with robot arm suppliers to produce arc welding robot systems. It is estimated that Japan has 3000 arc welding robots to only 300 in the US. By using a robot, it is projected that an arc welding system can be operational 70% of the time instead of 30% as at present. University research in welding is intense at robotic laboratories at MIT, CMU, University of California at Berkeley, Ohio State, and the University of Wisconsin. ***Iron Age,*** March 25, 1983, p. A-3.

LASER TOOLS. In October 1983 the Japanese government will unveil a small prototype "factory of the future," where laser-equipped machine tools will perform various metalworking processes all at once, instead of separately and sequentially. This 60 million dollar project is expected to cut production time in half. If successful, these tools will be commercially available by 1988. In addition to the metalworking milling, the lasers also can perform on-line heat treating, surface alloying, welding, and deburring. ***Fortune,*** February 21, 1983, p. 64.

Ted Blank is the publisher of *Smart Machines,* a monthly newsletter for people interested in the expanding field of robot applications.

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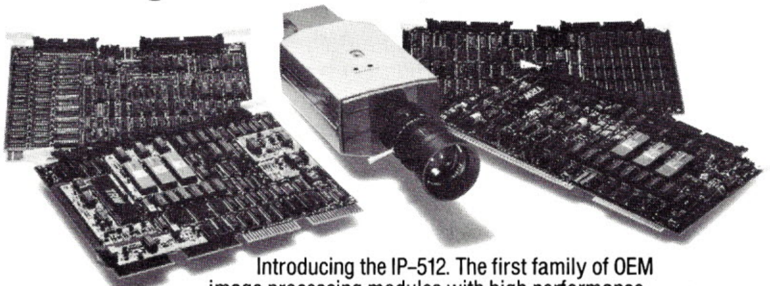

ROBOTICS AND THE LAW

ORGANIZING THE VENTURE

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The path from avocation to vocation in robotics, as in other areas of endeavor, is a confusing jumble of legal and commercial considerations, especially to those who are venturing forth on their own for the first time. The entrepreneur and businessperson in this area should anticipate and consider certain problems and contingencies related to establishing and operating a business. This article deals with some of the important issues surrounding the establishment of the venture, its form, scope, control, and internal arrangements.

Type of Business. There are three basic types of businesses: individual proprietorship, partnership, and corporation. In the selection of a business entity, the corporation is usually deemed the most serviceable of the three options. This is mostly because a corporation, in a legal sense, offers the necessary formalities, permanence, and limited liability. The key element here is often limited liability, which means that the owners of a corporate enterprise generally are not obligated personally for the debts of the corporation, as owners of an individual proprietorship or partnership are.

The entrepreneur, therefore, is more likely to choose the corporate form, because it offers a form of insurance at minimal costs. If the business fails or does poorly, the assets of the individuals involved usually are not subject to the risk of creditors' claims. The corporation offers certain other advantages and some disadvantages when compared with the two other forms. On balance, however, the preference in form is the corporation. This is especially the case when capital is required from a number of sources, management involves or will involve numerous operatives, and growth in its varied facets is anticipated and sought by the founders.

Choice of Jurisdiction. Once the corporation is designated as the business form, you must select the jurisdiction in which to organize the corporation. This will be the jurisdiction of one of the fifty states, US territories, or the District of Columbia. The federal law in most cases does not provide for incorporation. Picking the corporation's jurisdiction for organizational purposes involves a consideration of the initial and future physical locations of the business, certain corporate law wrinkles, taxation, and other relevant factors. By discussing your special circumstances with qualified legal counsel and accountants, you should be able to choose the most appropriate forum for your corporation with little difficulty.

Now we come to the nitty-gritty of the corporate formation—the area where the basic details of the incorporation process need to be thrashed out and decisions made in practically all situations. These issues may seem quite simple, and in the final analysis, they may well be. Nevertheless, they require careful consideration to avoid unnecessary delays, additional expenses, avoidable conflicts, and other pitfalls.

Name Selection. A corporation must have a name in order to begin its existence. Your initial reaction to this suggestion may be a confident smile and a nonchalant feeling that no problem could possibly exist about the name. Before hastily jumping to a conclusion, consider the legal and business parameters in the corporate name area. In various states, there are words that are forbidden for inclusion in corporate names and may be used only under special circumstances or with permission of a government department or agency. In the state of New York, for example, there are more than 27 such

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Mr. Cascone received his A.B. degree from Yale College and his L.L.B. from Columbia University and is admitted to the practice of law in the state of New York. He is a partner in the law firm of Rapaport & Cascone, 28 West 44th Street, New York, NY 10036 (212) 997-1040. A former lecturer in business law at Columbia University, he has spoken to many business groups and has written articles on corporate and international law matters for various publications. Mr. Cascone has extensive experience in venture capital, public offerings, mergers, acquisitions, divestitures, joint ventures, and general corporate matters.

words.

In addition, many states (if not all) generally prohibit the use of the same name by two or more corporations, and most restrict use of corporate names which are similar enough to confuse or deceive the public. There will be divergences in how strictly they enforce that rule. With a large population and many corporations, New York has developed a reputation as a strict enforcer of the corporate name similarity test.

If you are about to form a corporation, you may find the following rules of thumb useful. Consider the problem by yourself at the outset. Keep in mind the nature of your business. In the case of robotics, you may want some form of that word in the corporate name or you may prefer a form of your own name or some nondescriptive words or phrases that you find desirable or appropriate. Consult others about the name. If you have partners, they should participate in name selection. This is good politics as well as an intelligent use of other peoples' ideas.

Check name lists of businesses and telephone directories. As one of the preliminary devices in the name selection process, using name lists will spur your own thinking and will present at least a partial picture of the names that have already been taken and hence those that you should avoid.

When selecting names, derive a list of five to ten names for your corporation. Avoid choosing one at a time and sending in a single name check or reservation to the corporate authorities. Multi-name selection for checking may be slightly more expensive but can save time in the long run. Given the probable backlog of documents being filed with state officials, many months may be lost in the incorporation process if only one name at a time is submitted for approval. Avoid long, complicated names. They are time-consuming to write in legal and other documents, hard to remember, and difficult to understand. Keep the name as short and simple as possible.

Some may argue corporate names are insignificant, and for certain corporations they may well be right. But if you have visions of selling your corporation's securities to the public or reaching sophisticated or mass markets with your products and services, corporate names matter and require attention.

Choosing the Decision Makers. After the corporate name, you should consider the compositions of the corporation's board of directors, its officers, and shareholders. A corporation is a legal entity unto itself; it has certain constituent parts, or structure. At the most elemental level are shareholders, the owners of the entity. They own shares of stock in the corporation. Shareholders have certain powers, rights, and duties. They have the power to vote on certain issues, including the election of the board of directors, but generally they do not have the power, in their own right, to run the corporation.

Overall management and business policy formation of the corporation are powers vested in the board of directors. The board also elects the officers of the corporation: president, vice-presidents, secretary, treasurer. Theoretically, the officers of the corporation carry out the day-to-day operations of the corporate business under the general direction of the board. For a variety of reasons, the top officers in many corporations run the show, but in the end are accountable to the board and shareholders for their conduct of the business.

In a small corporation or newly organized one, the compositions of the three groups, shareholders, directors, and officers, often overlap. In other words, individuals may wear one or more of these hats. Remember, the ultimate power in any corporation lies in the voting equity (stock) owner. Whoever owns the majority of the outstanding voting stock controls the corporation.

That is not to say that directors and officers are more or less important. They too have certain powers in the total scope of things and at certain

times may be more influential in the affairs of the corporation than any shareholder. But the dominant shareholders usually pick themselves or their trusted representatives for positions on the corporate board and for important offices. Power flows from the shareholder group initially.

How then, should you, in organizing Omnipotent Robotics, Inc., select shareholders, board of directors, and officers? A compelling triad of factors in my estimation is: self-interest, competence, and money. If you are starting small with just yourself, a relative, and several employees, then you probably will monopolize all or nearly all positions for yourself. This is particularly so if you are putting up all the money for the venture and are the primary force, technologically and organizationally, in the business's development.

Most states require a minimum number of directors. This minimum number, in some states, may be equal to the number of shareholders if such number of shareholders is fewer than the minimum number of directors required. For example, if there is only one shareholder, in certain states, only one board member is necessary. Generally, it is either good corporate practice or a legal necessity to have another person serving as secretary if you are the president. The secretary's role usually includes taking the minutes or notes of directors' and shareholders' meetings.

Obviously, if two or more persons are starting a robotics business and are more or less equal in contributions to the business, one person will find it difficult to monopolize officerships, directors, and shareholdings. Selections should then be made on the basis of loyalty to and among the organizers and contributions to the business. If, for example, four individuals leave their jobs at approximately the same time to establish a robotics venture, contribute approximately the same amount of capital to it, and have similar levels of skill and experience, all other things being equal, there is a greater probability that each will hold an important officership, be a director and nearly equal shareholder in that corporation.

On the other hand, if one of the four leaves a job sufficiently in advance of the others and successfully devotes full time to developing a robotic product without any substantial contribution from the others, this person should have the largest equity ownership of the four and the most important office, as well as serving as director.

You may need capital from outside the organizing group. This may cause the corporation to sell its equity to nonfounders or nonworking interests for cash or other assets. To attract others to the corporation as employees, directors or consultants, you may have to hold out the carrot of stock options or equity *per se* at low prices, thereby enlarging the group of shareholders.

Directors obviously should be selected judiciously. You may seek to attract outside capital or credit by window-dressing your board with name directors—people with known reputations or impressive backgrounds. This approach has its drawbacks if it appears too transparent. You may also have on your board outside directors with needed skills and experience not possessed by the inside working directors.

In the initial stages of your business development or in a small corporate setting, shareholders, directors, and officers are like partners to one another. There is no substitute for knowing your would-be partners well before entering that business relationship. Once entered, it may not be that easy to undo without enormous expense or damage. Moreover, you may have to live with these initial personnel choices for some time. The success or failure of the venture may turn on such early decisions.

Background checks or references can be helpful, even for people you have known a long time. Loyalty to you as an organizer, honesty in dealings with you and others, capacity for hard work, enthusiasm for the project, competence in the job area assigned, and capacity to get along with people are some useful barometers when selecting people for different roles in your venture.

Keep in mind this is a business you are starting in a highly demanding and competitive field, not a social fraternity. You may be good friends with X at the place where you both work now. But will he make a good business partner for you? You may find the people who are personally closest to you are those you are least objective about in business.

Remember also that business requires team effort. Team effort does not mean every principal has to be a superstar. In fact, it may mean something quite different. Like athletic teams, business teams, to be successful, require a variety of skills and experience in their operation. Not everyone must (or should) do the same things well. In robotics, design, engineering, manufacturing, administrative, finance, marketing, and management skills are important. In the end, who will hold what positions will be determined by the needs of the business and the capacities and contributions of its organizers and their associates.

Capitalization. The initial capitalization of the corporation is another of the nitty-gritty issues that must be resolved in the incorporation process. The term initial capitalization does not mean, in this context, the money necessary to fund the corporation in the beginning. It relates to the corporation's capital structure, the kind and nature of the equity (common and/or preferred stock), the authorized amount or number of shares, and certain ancillary questions. The choices here are varied. A corporation can have straight common shares. It can have two types of common shares; that is, voting and non-voting, depending on the jurisdiction. Its capitalization can be made more sophisticated by the addition of different classes of preferred stock.

There are many differences between common and preferred stock. The primary distinction is that preferred stock receives priority in distribution of the corporate assets upon liquidation and the first claim of dividends upon declaration. It has

a preference in these areas over the common shares. Preferred shares, however, usually do not carry voting rights, and common shares usually do. You also have to determine at the outset the number of authorized shares of common or preferred stock as well as par value, if any, and the amount of such par value. For example, the corporation may have 1,000,000 common shares, with par value of $0.10 per share.

Whether you have different types and/or classes of stock initially depends upon the circumstances of your situation. If there is no real justification for different classes or kinds of equity, it is advisable to keep things simple and merely have voting common shares. If circumstances change, you can usually amend your certificate or articles of incorporation without much difficulty to add to or revise your capital structure.

The more difficult question may be the number of authorized shares to create. In a one-person corporation, you may be wise to keep the number of authorized shares low. If there are more than a few initial shareholders, of if more shareholders will be required in early financings, the authorized number should be larger in the beginning. One deterrent to large numbers of initial authorized shares is the carrying costs the corporation will have to pay in additional state taxes or initial filing fees.

Control Devices. A decision on preemptive rights is also on the early consideration list. Preemptive rights permit existing shareholders to purchase the approximate number of shares of any new issues of shares made by the corporation which will preserve their proportionate shares of such outstanding stock. For example, if there are 200 shares outstanding, and the corporation intends to issue 200 new shares to others, Shareholder A, who currently owns 50 shares, may subscribe to 50 of the new shares at the same price.

This is an anti-dilution measure that protects dividend, voting, and other ownership rights of existing shareholders. Depending on the jurisdiction of incorporation, preemptive rights may be created or eliminated by inclusion of an appropriate clause in the corporation's certificate or articles of incorporation. This is an important control device at the start of the corporation's existence and may be useful in a small group context.

Other control devices, depending on the jurisdiction of the organization, include voting trusts and shareholder agreements. Voting trusts allow the transfer of shares to a voting trustee (or trustees) with the power to vote such shares as the trustee sees fit for a limited term. This may be a useful device where you, as the dominant principal, have to give corporate stock to qualified personnel to induce them to work for the corporation, but yet you want to retain the voting rights related to such shares to control the corporation.

Shareholder agreements are another valid means of controlling the corporation by the insiders in certain

jurisdictions. Agreements of this nature may be entered into by two or more shareholders and encompass a variety of arrangements among them. In such agreements, they may, for example, agree to vote their shares together or by some special formula. This type of agreement may also include buy-back provisions for a shareholder's stock by another shareholder and/or the corporation upon death, disability, or certain other contingencies at specific prices or formula. Moreover, in such agreements, it may be determined which shareholders are to serve as directors and particular officers.

All these control devices—preemptive rights, voting trusts, and shareholder agreements—may be necessary during the early years of a corporation's existence. They are generally valid means of controlling a closely-held corporation. When stock ownership is about to be more broadly distributed either by way of public offerings or otherwise, these devices will have outlived their usefulness. Usually they will have been eliminated beforehand.

In the incorporation process, the basic corporate documents are the certificate (or articles of incorporation) filed with the appropriate state authorities, the bylaws, the minutes of the meetings of the incorporators, directors, and shareholders, and certain ancillary documents. While it is important for you to consider the above issues carefully before incorporation, their initial resolutions are not cast in concrete and can be altered by following appropriate procedures later on. Changes, amendments, and additions to these documents, properly authorized by the officers, directors, and the shareholders, if necessary, will generally accomplish your objectives. □

Reader Feedback

To rate this article, circle the appropriate number on the Reader Service card.

60	70	80
Excellent	Good	Fair

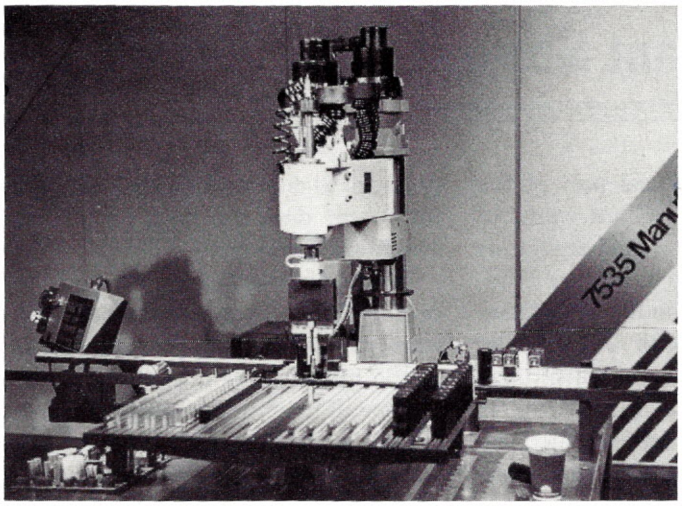


Photo 11a. The IBM pick and place robot assembling printed circuit boards.

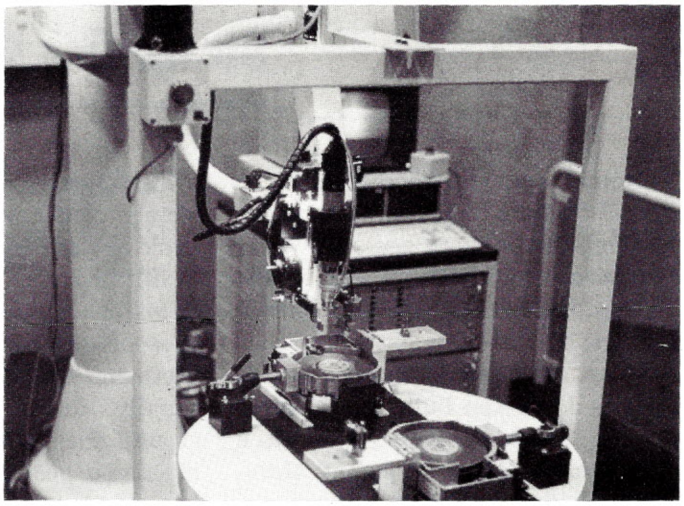


Photo 11b. The Intelledex robot assembling hard disk drives.

Continued from page 13.

Two demonstrations of high technology manufacturing were provided by IBM and Intelledex. As seen in photo 11(a), IBM demonstrated its pick-and-place robot in a printed circuit board assembly operation. As far as manufacturing automation is concerned, this demonstration is at the leading edge of electronics technology. At a similar leading edge [photo 11(b)], Intelledex demonstrated an application critical to modern computer technology—the assembly of hard disk platters used in mass storage.

Just as the Spine was the most unusual manipulator, the prize for the most unusual and evocative mobile robot concept has to go to the Odex I "functionoid" device. We did not obtain any pictures at the Wednesday afternoon press conference, but we expect to have more information on this device in forthcoming issues of *Robotics Age.*

Produced as a feasibility project, Odex I is not commercially available yet. It does, however, demonstrate that walking robots are possible and capable of many interesting mobility characteristics. The Odex I was shown (on film) walking, turning, and lifting up the back of a small pickup truck.

Although lifting the back end of a pickup truck demonstrates brute power and strength, there was one maneuver in the demonstration film which epitomizes this new concept's capabilities. The operator commanded the Odex I's control computer to walk up onto the bed of the pickup truck and then back out. This was done without the benefit of any kind of ramp. Could the Odetics concept of a functionoid be the solution we all need for a household mobility concept? A functionoid might solve the wheeled robot's puzzling problem of maneuvering up and down stairs.

Automated Warehouse Simplifies Giant Storage

Robots and remote control doors have become significant tools in frozen food storage centers, where subzero temperatures can make things difficult for ordinary human beings.

Four automated stacker cranes (photo 1) do the bulk of the bone-chilling work at Giant Food, Inc.'s new storage facility in Jessup, Maryland. The unmanned machines can pick up frozen food pallets, take them into high-rise storage locations, and even retrieve the items when they are needed.

"I believe we have the only totally automated storage and retrieval system of this kind in a −10° environment," says Al Lechert, vice president of building and construction for Giant.

The storage center, a 74-foot high rise encompassing 22,168 square feet, is part of Giant's new frozen food distribution center and ice cream processing plant. Giant built the facility for $14 million and spent an additional $6 million for special equipment. Fewer than 10 people are required to venture into the frigid storage facility.

Each item delivered to the storage center is given a series of numbers, dictating what the item is and where it should be deposited in the warehouse. The 70-foot-tall cranes are linked to an automated case-selecting machine capable of selecting 3,600 cases of frozen food per hour. All mechanized material handling equipment is operated under computer control. Information from the center at Giant's headquarters in Landover, Maryland has been integrated into the system, making it complete. Each case is tracked from the time it is received until it is delivered to one of Giant's 131 stores in Maryland, Virginia, and Washington, D.C.

Insulation is a crucial part of the storage center, since Giant wants to avoid any spoilage, wasted energy, or health hazards. The walls are 5 inches thick. Under the tower is 15 inches of concrete with 5 inches of urethane insulation beneath that. Finally, under the insulation is ground that has been warmed by reclaimed heat piped in from compressors to ensure the earth beneath the tower does not shift and cause structural problems.

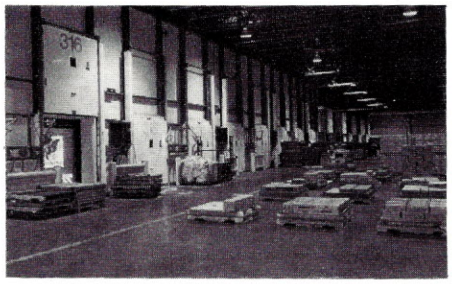
Crucial insulation areas are the center's 56 doorways. The doors lead from one room to another, as well as to the outside. "If it isn't right, the doors will frost on the inside and will create a real mess," points out George Krug, vice president of St.

A robot stacker crane lifts frozen food pallets onto shelves at Giant Food Inc.'s new frozen food storage center in Jessup, MD. The 70-foot-tall unmanned crane stacks and retrieves goods in the chilly storage facility, sparing workers the subzero temperatures. Jamison doors open automatically for the cranes.

Onge Ruff & Associates, Inc., of York, Pennsylvania, the architectural firm that designed the facility.

All 56 doors in the Giant building are from the Jamison Door Company of Hagerstown, Maryland. Many different door types and styles, most with a molded plastic finish, are installed throughout the refrigerated areas. Mark II vertical sliding doors are used at the loading docks, featuring clear, shatterproof, plexiglass vision panels. In the storage area are Jamison Mark II Electroglide® horizontal sliding doors (photo 2), Jamolite® freezer and cooler doors, and Mark II manual horizontal sliding fire doors, all designed to make sure temperatures as low as -10, -20, and even -35 degrees Fahrenheit are maintained. Jamison was selected from among several door manufacturers for its competitive price and the quality of its product.

The inside doors are white plastic: outside doors are coordinated to match Giant's color scheme, another specialty of Jamison. Color chips are given to the company, and pigments are mixed to match any color.



Pallets line the floor inside the shipping and receiving dock area. A number of Jamison vertical sliding doors are used for temperature control.

Since some of the doors are automated and they open for the unmanned cranes and for goods on conveyor belts, it is important that they close properly. "The doors are vital in that it's an automated warehouse," Krug said. If they fail, "it adds to the heatload and adds to the operational costs." Sam Thurston, Giant's vice president for distribution, points out, "doors that work and provide the proper sealing are very, very important in an operation like this."

Thurston says he is pleased with how the frozen food plant has been operating so far, noting he is particularly pleased with two improvements in particular: better space utilization and better working conditions.

"We're trying to do our business in the smallest possible space," he said. The vertical construction is utilized to gain the maximum use of space while maintaining the most efficient use of energy. "It's capable of storing more than 6,000 pallets of frozen foods, while the old warehouse in Landover could store only 4,200 pallets," said Lechert, adding that up to 125 tons of goods can move in and out of the building in a single day. The tall cranes make possible the vertical design of the building.

In addition, the use of unmanned cranes limits the number of people who must work in the subzero temperatures that demand anyone walking through to wear Arctic clothing. "It minimizes the number of people subjected to the relatively harsh environment," Thurston points out. □

AM Award to Joseph Engelberger

American Machinist has named the father of robotics, Joseph F. Engelberger, the winner of the eighteenth AM Award. The award recognizes Engelberger, founder of Unimation, Inc. (Danbury, Connecticut) and the Robot Institute of America, for pioneering the industrial robot, creating a new industry and providing a new approach to industrial automation.

In 1956, 31-year-old Engelberger met George Devol, an independent inventor for Sperry Gyroscope and General Electronic Industries, who had a patent application for "programmed article transfer." As general manager of the small aerospace operation at Manning, Maxwell and Moore (Stamford, Connecticut), Engelberger started experimenting under Devol's patent as a sideline for his division. The company, however, would not fund more than rudimentary research or let the pair build anything.

When Manning, Maxwell and Moore decided to get out of the aerospace business in 1957, Engelberger enlisted the help of Norman Shafler, the founder of the military vehicle manufacturer, Consolidated Diesel Electric Company (now Condec), to purchase the 160-worker aerospace division. Engelberger and his new Consolidated Controls Corporation set up shop in a garage and began making their aircraft components.

Consolidated Controls built its first prototype universal helper, dubbed a Unimate by Engelberger and Devol, in 1959; it was installed at a General Motors plant. The first production Unimate was shipped in 1961. It was initially used to load and unload machines, and the first commercial robots, sent to GM and Doehler-Jarvis, tended hot diecasting machines. Unimation, Inc. was founded in 1962 as a joint venture between the Pullman Corporation and Condec.

Robotics gained widespread attention in America in the early 1970s. The Illinois Institute of Technology's Research Institute held the first international symposium on industrial robots in 1970. In 1974, largely through Engelberger's efforts, the Robot Institute of America was founded as the only trade association in the United States dealing with robotics.

CIRCLE 11

CIRCLE 12

Calendar

Continued from page 4

telligence. Contact: Karlsruher Kongressund Ausstellungs-GmbH, Festplatz 3, PO Box 1208, D-7500 Karlsruhe 1.

The IJCAI-Conferences are the main forum for the presentation of AI research and technology to an international audience. The goal of IJCAI-83 is to promote scientific interchange within and between all subfields of artificial intelligence among researchers. Topics to be covered include: robot software and hardware, computer vision, natural language and speech processing, expert systems, game playing, and handwriting readers.

August 9–11, 1983. World Congress on Human Aspects of Automation. University of Michigan, Ann Arbor, Michigan. Contact: Public Relations Department, SME, One SME Drive, PO Box 930, Dearborn, Michigan 48128. Phone: (313) 271-1500.

The Society of Manufacturing Engineers, Robotics International, the Computer and Automated Systems Association, and the Association for Finishing Processes are sponsoring this three-day conference with the theme "Living with Automation." Topics to be discussed include: job displacement, training and retraining, shorter work weeks, the quality of work life, new management practices, and management/labor relations.

August 22–26, 1983. National Conference on Artificial Intelligence (AAAI-83). Washington Hilton Hotel, Washington, DC. Contact: Michael R. Genesereth, Computer Science Department, Stanford University, Stanford, California 94305. Phone: (415) 497-0324.

AAAI-83 is the third national conference sponsored by the American Association for Artificial Intelligence. The conference's purpose is to promote research in the field of artificial intelligence by bringing together experts from government, industry, and academia. The topics of interest are: knowledge representation, problem solving and inference, search and learning, natural language, speech and vision processing, robotics, and expert systems.

SEPTEMBER

September 19–21, 1983. 9th Annual Advanced Control Conference. Fowler Hall, Purdue University, West Lafayette, IN. Contact: Henry Morris, Conference Coordinator, Control Engineering, 1301 South Grove Avenue, PO Box 1030, Barrington, IL 60010. (312) 381-1840.

This year's conference is entitled "Learning Systems and Pattern Recognition in Industrial Control." Conference subjects include speech recognition, intelligent vision systems, robotics, and artificial intelligence.

September 19–30, 1983. 2nd Annual Computer Science at UCLA. UCLA Extension, Los Angeles, CA. Contact: UCLA Computer Science Department, 3732 Boelter Hall, Los Angeles, CA 90024. (213) 825-2929.

Classes are abridged versions of regular UCLA Computer Science Department courses. Plenary sessions provide a special opportunity to hear outstanding leaders in the computer field. Of particular interest are courses in: artificial intelligence, computer networks, pattern recognition, and numerical methods.

A Table of Contemporary Manipulator Devices

	Memory Devices				Programing Method				Memory Capacity	Potential Application													Education
										Material Handling	Machine Load/Unload						Tool Manipulation				Assembly	Inspection	
	Solid State Electronics	Magnetic Tape or Disk	Air Logic	Mechanical Step Sequencer	Keyboard	Pendant	Walkthrough	Mechanical Set-up			Die Casting	Forging	Plastic Molding	Machine Tools	Investment Casting	General	Spray Painting	Welding	Machining	Other			
Copperweld Robotics, CR-5	✓					✓			256 steps/points	✓		✓	✓	✓	✓					✓	✓		
Copperweld Robotics, CR-10	✓					✓			250 steps/points	✓	✓		✓							✓	✓		
Copperweld Robotics, CR-50	✓					✓			250 steps/points	✓	✓		✓								✓		
Copperweld Robotics, CR-100	✓					✓			256 steps/points					✓							✓		
Cybotech, C80	✓				✓	✓			1000 points	✓								✓	✓			✓	
Cybotech, H8	✓				✓	✓			1500 points	✓								✓	✓		✓	✓	
Cybotech, H80	✓				✓	✓			1500 points	✓								✓	✓			✓	
Cybotech, P15	✓	✓				✓	✓		1500 points								✓			✓			
Cybotech, V15 Electric Robot	✓	✓			✓	✓	✓		1,500 points	✓						✓					✓	✓	
Cybotech, V80	✓				✓	✓			1500 points	✓						✓		✓	✓			✓	
Cyclomatic Industries, Ironman I						✓			128k bytes									✓					
DeVilbiss, TR-3500S	✓	✓					✓		128 minutes	✓							✓	✓					
DeVilbiss, TR-3500W	✓	✓				✓	✓		128 minutes	✓								✓		✓			
Gallsher Enterprises, Gemini Concept					✓																✓	✓	
Gametics Kelate Model 524	✓	✓				✓			150 steps	✓													
GCA, XR6 Extended Reach					✓	✓			1500 points	✓						✓		✓	✓				
GCA, B1440					✓	✓			999 steps	✓						✓		✓					
GCA, P300H						✓	✓		511 steps	✓											✓		
GCA, P800					✓	✓			999 steps	✓								✓			✓		
GCA, P300V						✓	✓		511 steps	✓											✓		
General Electric, A12 Allegro	✓	✓			✓	✓										✓			✓		✓	✓	
General Electric, AW-7	✓	✓				✓			464 steps									✓					
General Electric, MH33						✓			435 steps	✓						✓							
General Electric, GP132						✓			290 steps							✓		✓					
General Electric, GP66						✓				✓								✓					
General Electric, P-5	✓	✓				✓			448 steps									✓	✓		✓		
General Electric, S-6	✓	✓				✓			464 points								✓						
General Numeric, A-0	✓				✓	✓			up to 6000 points	✓											✓		
General Numeric, Series M, Model 0						✓			300 points	✓			✓	✓									
General Numeric, Series M, Model 1						✓			300 points	✓			✓	✓							✓		
General Numeric, Series M, Model 3	✓				✓	✓			up to 6000 points	✓				✓									

Manufacturer, Model	Telephone	Typical Price	Load Carrying Capacity (lbf)	Repeatability (in)	Maximum Tip Speed, No Load (ips)	Coordinate System				Maximum Movement						Type of Drive			Control: Continuous Path, Controlled Path, Point-to-Point (C,C*,P)	
						Cartesian	Cylindrical	Spherical	General	Manipulator Reach	Manipulator Elevation	Manipulator Rotation or Translation	End Effector Pitch (deg)	End Effector Yaw (deg)	End Effector Roll (deg)	Electric	Hydraulic	Pneumatic	Non-servo	Servo
Copperweld Robotics, CR-5	313/585-5972	$ 12,800	5	0.003			✓			0″	2″	200°						✓		
Copperweld Robotics, CR-10	313/585-5972	$ 16,800	10	0.003	12		✓			12″	2″	200°	—	—	270			✓	P	
Copperweld Robotics, CR-50	313/585-5972	$ 23,500	20	0.01	12		✓			18″	5″	200°	—	—	270			✓	P	
Copperweld Robotics, CR-100	313/585-5972	$ 49,500	30	0.002		✓				24″	12″	24″						✓		
Cybotech, G80	317/298-5136	$225,000	175	0.008	50	✓				59″	39.4″	78.8″	335	210	334		✓			C
Cybotech, H8	317/298-5136	$ 90,000	17	0.004		✓				20″	20″	320°	210		345	✓				C
Cybotech, H80	317/298-5136	$162,000	175	0.008	50	✓				135°	63″	± 135°	335	210	344		✓			C
Cybotech, P15	317/298-5136	$164,000	33	0.2	78				✓	+ 55° to − 35°	± 40°	± 115°			± 175		✓			C
Cybotech, V15 Electric Robot	317/298-5890	$ 92,500	33	0.004	68	✓				66″	71″		± 105	± 175	± 180	✓				P
Cybotech, V80	317/298-5136	$151,000	175	0.008	50				✓	78.8″	118.2″	± 135°	335	210	344		✓			C
Cyclomatic Industries, Ironman I	714/292-7440	$130,000	50	0.010		✓				36″	56″	96″				✓				
DeVilbiss, TR-3500S	419/470-2169	$ 95,000	12-50	0.06	72		✓		✓	124″	81″	93°	176	176	210		✓			C, P
DeVilbiss, TR-3500W	419/470-2169	$ 80,000	50	0.16	36				✓	124″	80.5″	93°	176	176	210		✓			C, P
Gallsher Enterprises, Gemini Concept	919/725-8494	$ 15,000	5	0.001		✓				24″	12″					✓		✓		
Gametics Kelate Model 524		$ 50,000	50	0.03	30		✓			26″	38″	270°	220		220		✓			P
GCA, XR6 Extended Reach	312/369-2110	$100,000	2,240	0.02		✓				20′	84″	40′	330	210	330					C, P
GCA, B1440	312/369-2110	$ 55,000	110	0.02					✓	39.4″	27.6″	300°	120	300	180	✓				C, P
GCA, P300H	312/369-2110	$ 30,000	11	0.004					✓	23″	3.9″	180°		300		✓				C, P
GCA, P800	312/369-2110	$ 65,000	66	0.02					✓	54″	91.8″	270°	210		300	✓				
GCA, P300V	312/369-2110	$ 45,000	11	0.004					✓	28″	41.4″	270°	210		270	✓				
General Electric, A12 Allegro	203/382-2876	$125,000	14	0.001	45.3	✓				12.2″	10.4″	51.2″	98	36	360	✓				P
General Electric, AW-7	203/382-2876	$150,000	1,323	0.04	240	✓										✓	✓			
General Electric, MH33	203/382-2876		33	0.1				✓		47″		360°				✓				
General Electric, GP132	203/382-2876		132	0.29					✓	82″						✓				
General Electric, GP66	203/382-2876		66	0.039				✓		46″						✓				
General Electric, P-5	203/382-2876	$ 65,000	22	0.008	39.4	✓				49.5″	63″	300°	± 25		185	✓				C
General Electric, S-6	203/382-2876	$ 75,000	6.6	0.19	69				✓	76″	122″	150°	250	250	250	✓	✓			C
General Numeric, A-0	312/640-1595	$ 32,000	22	0.002			✓			11.8″	11.8″	300°				✓				C
General Numeric, Series M, Model 0	312/640-1595	$ 20,000	22	0.02			✓			5.9″	5.9″	180°				✓				
General Numeric, Series M, Model 1	312/640-1595	$ 28,000	44	0.039			✓			72.6″	57.1″	210°				✓				P
General Numeric, Series M, Model 3	312/640-1595	$ 70,000	110	0.039			✓			47.2″	47.2″	300°	190		300	✓				

This material is authored by Bernard Roth, a professor in the Design Division of the Mechanical Engineering Department at Stanford University in Stanford, California.

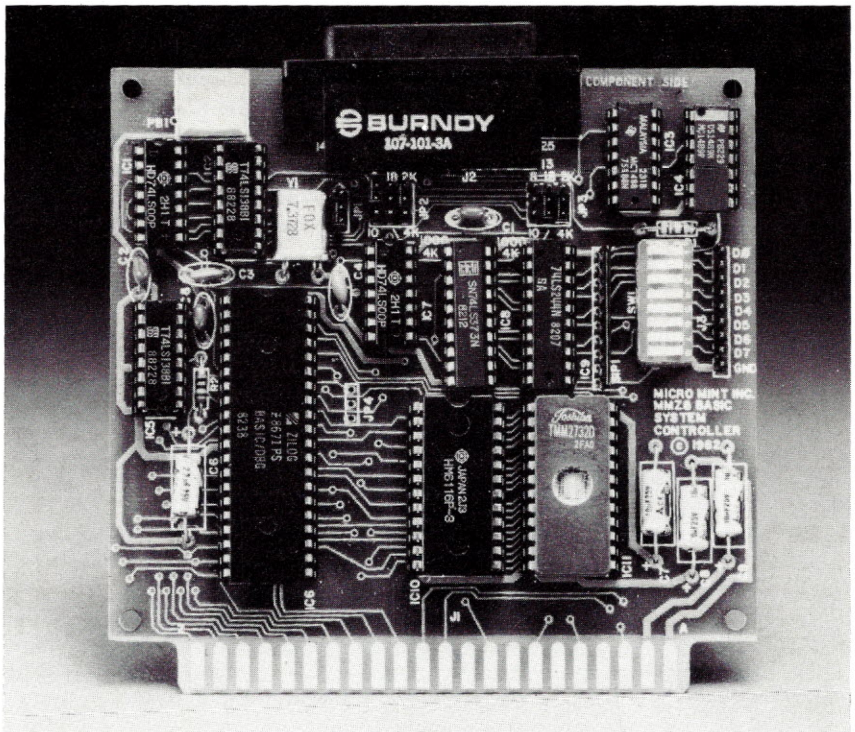
These tables are reproduced from the Stock Drive Products Data Book, Volume 2 available at $7.95 from: Educational Products, P.O.Box 606, Mineola, New York 11501.

New Products

Z8 BASIC System Controller Board

The Z8 BASIC System Computer/Controller features the Zilog Z8671 and contains a tiny BASIC interpreter, up to 6K bytes of RAM and EPROM memory on the board, an RS-232-C serial interface with switch-selectable data transfer rates, and two parallel ports. The 4 by 4½ inch self-contained board is fully expandable to 124K bytes and has been optimized for use as a dedicated controller. Connecting a CRT terminal allows immediate programming in BASIC or machine language. Programs can be transferred to 2732 EPROMs with optional EPROM programmer for auto-start application. The cost is $199.00 in single quantity; $127.00 each in quantities of 100. For information, contact: The Micromint, Inc. 561 Willow Avenue, Cedarhurst, New York. Orders only: 1-800-645-3479.

CIRCLE 26



Attention Creative Designers . . .

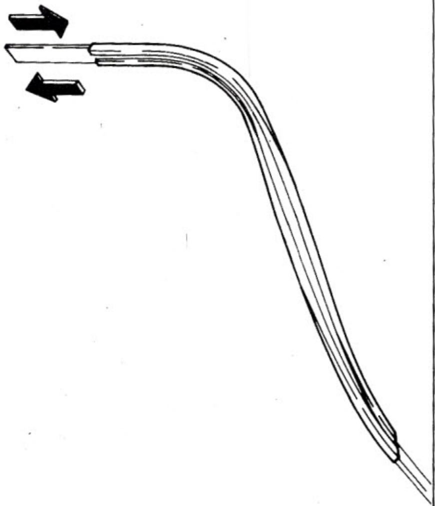
We recently received information from Du Pont regarding a useful structural material for mechanical power transfer. The product, called Dymetrol elastomeric tape, was introduced in 1978. Since 1979 it has been used in the automotive window regulator mechanisms of production cars. A Du Pont article titled *"Dymetrol* Elastomeric Tape Drives Automotive Energy Transfer Systems" describes a number of potential automotive uses from windshield wipers to convertable top mechanisms.

Actual automotive uses include application in passive restraint systems of production cars starting in 1981. Nonautomotive products using this material include a model of the Genie automatic garage door opener made by Alliance Manufacturing. In the garage door opener, Dymetrol tape substitutes for the usual heavy chain drive.

The material is flexible, light weight and suitable for use in a push-pull mechanical arrangement. We said "aha" when the material came in, thinking of possible uses in industrial and personal robotics designs.

A potential application would be to run Dymetrol strips through guide tracks or bushings in order to offset a mechanical power source from its place of application. According to the Du Pont literature, the Dymetrol material in tape form has edge bend and nonbind properties that allow it to transfer power smoothly and quietly within formed metal or plastic tracks as shown in the illustration reproduced here.

In our opinion this material has many unique and imaginative uses in positioning mechanisms useful in robotics design. For those wishing to go further, Du Pont will supply a free kit of Dymetrol samples to individuals requesting information on company letterhead. Write The Du Pont Company, Marketing Communications Department, Wilmington, Delaware 19898. Mention that you read about it in *Robotics Age.*

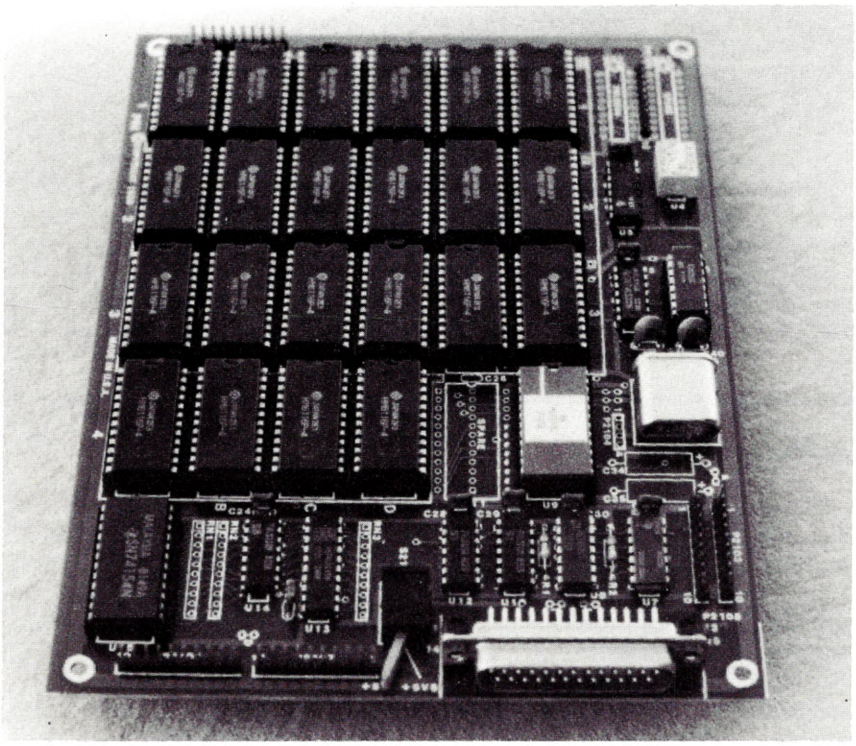


CIRCLE 27

New Products

Hero-I Accessories

Perbotics offers three products designed to increase the performance of the Heath Hero-I robot. The 44K byte programmable memory board expands Hero I's on-board memory to 48K bytes and an RS-232-C port. The 8K byte memory board provides extra board space for user-designed memory expansion. A cassette tape is available which provides load and dump routines which work through the RS-232-C port. The tape also includes memory verification routines. The 44K RAM board lists for $795.00, 8K RAM for $395.00, and the cassette tape for $49.00. For more information contact: Perbotics, 17072 Emerald Lane #C, Huntington Beach, California 92647. (714) 847-7846. CIRCLE 28



Seeq Technology Unveils Adaptive Microcomputer

Seeq Technology, Inc. has announced the industry's first 5-volt-only E²ROM, 8-bit microcomputer. Based on Texas Instruments' TMS7000 family, the new chip, the Seeq 72720 (adaptive microcomputer), is self-programmable and uses 2K×8 E²ROM (electrically erasable read-only memory) in place of TI's traditional ROM.

Seeq's model 72720 will open new markets for commercial, industrial, and military products. It has been designed for applications that require a nonvolatile memory capable of being erased and written without its removal from the system. It will find wide use wherever dynamic or remote configuration of the system is needed.

Applications for the 72720 include remotely programmed systems (for maintenance, diagnostics, and firmware updates), robotics, instruments, process control, household appliances, and telephones.

For more information, contact: Sterling Hager, The Strayton Corporation, 5 William Street, Wellesley, Massachusetts 02181, (408) 727-1188. CIRCLE 29

Machine Vision Literature

A technical specifications bulletin describing the features of the ERMAC® 2500 Series Machine Vision System is available from Everett/Charles Automation Systems.

The bulletin contains complete operational and dimensional information, as well as specifications on equipment configurations and installation.

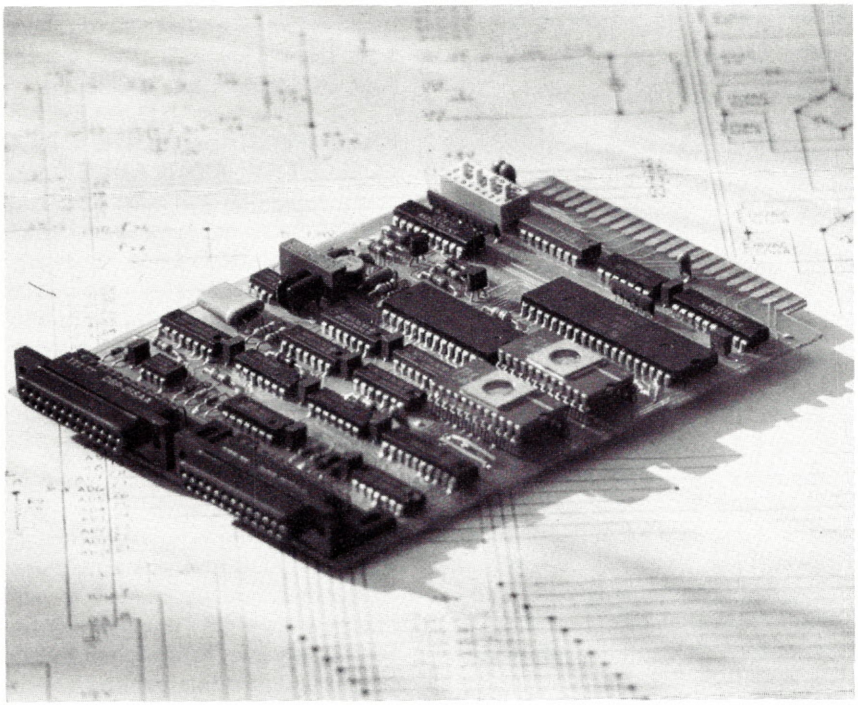
The ERMAC® 2500 Series Machine Vision System consists of a computer equipped with a camera to perform real-time visual analysis in a high-speed, repeatable manner.

Everett/Charles Automation Systems is chartered to design, manufacture, and market quality automation equipment. For information, contact: Paul Paulsen, 700 East Harrison Avenue, Pomona, California 91767. (714) 625-5571.

CIRCLE 30

New Products

Microtelemetry Module



The Software Science Microtelemetry Module is an 8-channel, 8-bit, analog data acquisition system in which a single-chip microprocessor supervises the operation of both the analog-to-digital converter and communication to and from a host computer. Eight 0-5V analog inputs are measured, and the data from each can be sent via an RS-232-C interface.

Commands are sent from the host device in decimal ASCII, and data for each of the eight channels is transmitted to the host device as a three-digit decimal ASCII number. Commands received from the host device determine the channel or channels to be sent and format of the output. In addition, there are 12 TTL output lines that can be programmed from the host device. Up to 256 Microtelemetry Modules can be linked together on a single RS-232-C line and addressed individually. The network is configured as an open ended daisy chain.

Each Software Science Microtelemetry Module consists of a single 4.5 inch by 6.5 inch printed circuit board with a dual 22-pin card edge at one end and two DB25S sockets at the other end. The dual 22-pin connector is an industry standard type with fingers on 0.156-inch centers. The DB25S connectors are mounted at the top edge of the printed circuit board to provide easy access to the connectors while the board is mounted in a card frame. Power supply and analog input, as well as the digital output lines, are terminated on the dual 22-inch pin card-edge connector.

The TEMPACHEAP version of the Software Science Microtelemetry Module includes internal linearization tables and references to allow the direct connection of thermistors to the analog inputs providing ± 1 degree Fahrenheit accuracy over a -20 to $+140$ degree range. Single quantity price is $249.00, including the TEMPACHEAP option. Quantity discounts are available. For information, contact: Software Science, PO Box 44232, Cincinnati, Ohio 45244. (513) 831-1644.

CIRCLE 31

Servo Controller

The Model 102 Intelligent Servo Control Computer provides the capability to control a DC servo position or velocity loop from the STD BUS. The 102 uses an incremental encoder for position feedback and the STD BUS for commands. By using sophisticated control algorithms, the 102 develops the appropriate analog velocity signal to feed a standard servo amplifier. A complete memory check is made after power-up, and feedback inputs are verified constantly. Any faults are indicated by a bank of six LEDs. An isolated fail-safe watchdog timer signals external equipment of emergency conditions.

Typically, several 102s are combined into a multiaxis system. Such a system can coordinate up to 16 axes of motion simultaneously. Features include: Allows straightforward control of complex position profiles from the STD BUS. Operating parameters such as acceleration, deceleration, and travel limits are programmable. Encoder input multiplied by four to facilitate lower resolution encoders. Automatic accel/decel ramps on all position changes. Constantly verifies encoder input integrity during operation. Has onboard fail-safe watchdog timer with isolated contact. Encoder inputs optically isolated and differential to enhance noise immunity. Feedback polarity reversible with programming jumper. 128 bytes of dual-port RAM uses semaphore system for rapid parallel communications. Loop update time adjustable from 700μs to 20 ms. Can be combined with other Intelligent Servo Control Computers to simultaneously coordinate up to 16 axes.

Some applications are robotics, machine tool control, indexing tables, conveyor control, servo positioning, tracking systems, x-y tables, simulators, and education. For information contact: Integrated Technologies, Inc., 444 West Maple Building F, Troy, Michigan 48084. (313) 362-4466.

CIRCLE 32

New Products

MicronEye

The MicronEye is a complete vision system for a computer system. Capable of 256 by 128 resolution and operating speeds of up to 15 frames per second, the MicronEye transmits images into the computer's memory, enabling graphics display, image analysis, image storage to disk, and so on.

The MicronEye makes graphics input simple. Possible applications include program animation, security, automated process control, digitizing, pattern analysis, robot vision, and text recognition. Sample programs and driver routines (including source code) are provided on an unprotected diskette. Complete software documentation is included, as well as information for developing custom applications.

The MicronEye bullet costs $295 in single units and is currently available for the Apple II+, Apple IIe, IBM PC, Commodore 64, and TRS-80 Color Computer. Dealer inquiries are invited. Complete information on the MicronEye and related products is available from: Micron Technology, Inc., 2805 East Columbia Road, Boise, Idaho 83706. (208) 383-4050.

CIRCLE 33

Microcomputer-Aided Design and Drafting

AutoCAD is a two-dimensional computer-aided drafting and design package which runs on 8-bit and 16-bit microcomputers under CP/M-80, CP/M-86, or MSDOS/PCDOS. It is a general-purpose package, suitable for a wide variety of applications, including architectural and landscape drawings, mechanical, electrical, chemical, structural, and civil engineering, and printed-circuit design.

AutoCAD acts like a word-processor for drawings. It lets the user make drawings from simple components such as lines (of any width), circles, arcs, and solid-filled areas. Drawings may be annotated with text of any size, inserted at any point and at any orientation. The drawings can be stored on disk and in turn used as components in other drawings. The ability to define parts libraries simply by drawing them, and to write custom menus (via ordinary text files), allows specialized application systems to be developed easily.

Drawings can be created through keyboard commands, with a light pen and on-screen menu, or from existing paper drawings via a digitizing tablet. The large set of editing commands allows drawn objects to be moved, copied, modified, erased, rotated, and scaled vertically and horizontally. Repetitive patterns such as brick walls or memory arrays can be generated automatically. A full bidirectional zoom facility allows working on the drawing at any level of detail.

The package maintains data internally in full floating-point format, allowing a ratio of at least a million to one between largest and smallest objects. Objects may be aligned to grid boundaries or forced to run vertically and horizontally only. An optional alignment grid may be displayed on the screen as a drawing aid. Up to 127 layers and colors may be used, allowing selective viewing or plotting of drawings as if on transparent overlays.

Drawings can be plotted to any desired scale at any point during the drawing process. Each drawing color may be assigned to a plotter pen and line type. Utilities supplied with the package can convert drawings to or from an ASCII text file. This allows user programs to process information entered in graphic form through AutoCAD, or, conversely, the viewing or editing with AutoCAD of drawings produced by data from user programs.

Modular device drivers and high-level language implementation allow new system configurations to be implemented easily. Systems currently supported include CP/M-80 machines with the Scion Microangelo graphics subsystem and optional light pen, the Victor 9000 with 256K RAM and optional Sun-Flex Touch Pen, and the IBM Personal Computer with 128K RAM and monochrome and color graphics card. All systems support Summagraphics and Houston Instruments digitizers, and the complete range of both Hewlett-Packard and Houston Instruments plotters.

For more information, contact: Mike Ford, Autodesk Incorporated, 16 St. Jude Road, Mill Valley, California 94941, (415) 381-1819.

CIRCLE 34

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